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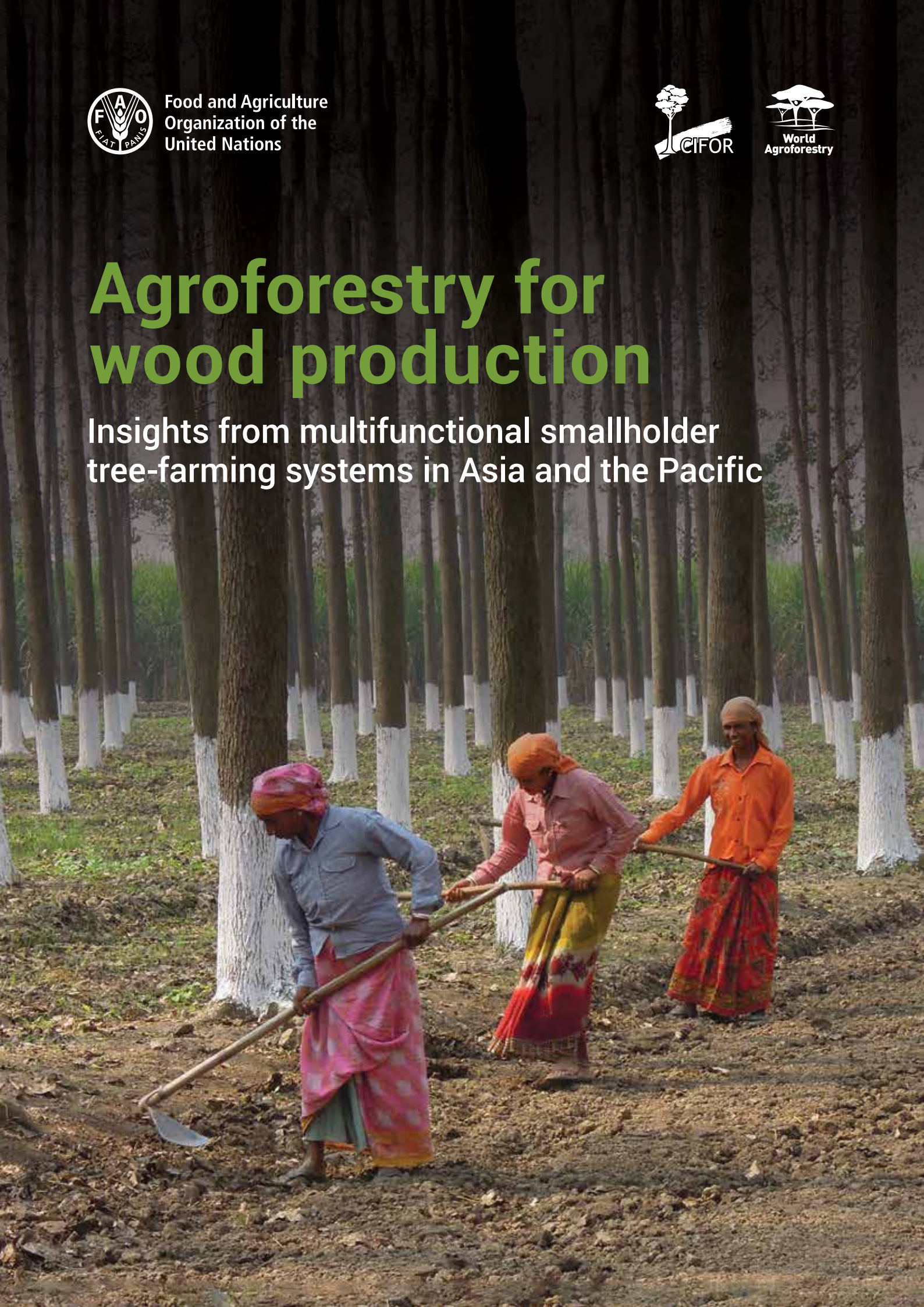
Agroforestry for wood production

Insights from multifunctional smallholder tree-farming systems in Asia and the Pacific



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Agroforestry for wood production

Insights from multifunctional smallholder tree-farming systems in Asia and the Pacific

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ACSFI	Advisory Committee on Sustainable Forest Industries
APFC	Asia-Pacific Forestry Commission
ASEAN	Association of Southeast Asian Nations
BMAC	Binh Minh Agroforestry Cooperative
CAFRI	Central Agroforestry Research Institute
CIFOR-ICRAF	Center for International Forestry Research and World Agroforestry
CoC	Chain of Custody
CLT	Cross-laminated timber
CSR	Corporate Social Responsibility
ESCAP	Economic and Social Commission for Asia and the Pacific
EUDR	European Union Deforestation Regulation
EWP	Engineered wood product
FAO	Food and Agriculture Organization of the United Nations
FCLP	Forest and Climate Leaders' Partnership
FFF	Forest and Farm Facility
FFPO	Forest and farm producer organizations
FLR	Forest and landscape restoration
FPIC	Free, Prior and Informed Consent
FPMIS	Field Programme Management Information System
FSC	Forest Stewardship Council
FTA	Forests, Trees and Agroforestry
GCF	Green Climate Fund
GIAHS	Globally Important Agricultural Heritage System
GMT	Green metric tonne
HDI	Human Development Index
ICAR-CAFRI	Indian Council of Agricultural Research – Central Agroforestry Research Institute
IFC	International Finance Corporation
IIED	International Institute for Environment and Development

IUCN	International Union for Conservation of Nature
IPC	International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment
IPM	Integrated pest management
IRR	Internal Rates of Return
ITTO	International Tropical Timber Organization
IUFRO	International Union of Forest Research Organizations
LVL	Laminated veneer lumber
M&E	Monitoring and evaluation
NAP	National Agroforestry Policy (India)
NDC	National Determined Contributions
NGO	Non-governmental organization
NPV	Net Present Value
NRM	Natural resource management
NWFP	Non-wood forest product
PEFC	Programme for the Endorsement of Forest Certification
PES	Payment for ecosystem services
PFA	Production forest area
PNG	Papua New Guinea
RECOFTC	Regional Community Forestry Training Centre for Asia and the Pacific
RWE	Roundwood equivalent
SDG	Sustainable Development Goal
TOF	Trees outside forests
VFNU	Viet Nam Farmer's Union

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The study was written by Andras Darabant (FAO), Priya Pajel (FAO), Faustine Zoveda (FAO) and Himlal Baral (CIFOR-ICRAF) and was carried out under the overall technical coordination of Sheila Wertz-Kanounnikoff (FAO).

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Executive summary

Background and objectives of the report

In response to rapidly increasing wood demand in Asia and the Pacific and concurrent limitations in expanding wood production from natural forests and plantations, smallholder tree-farming systems are becoming increasingly important suppliers of wood across the Asia and the Pacific region. Drawing on the recommendations of the Asia-Pacific Forestry Commission, the present report provides a detailed overview of these systems including enabling factors and strategies for enhancing production, complemented by illustrative case studies. It also offers targeted recommendations for policymakers to facilitate further upscaling of wood production from smallholder systems.

Smallholder wood production systems as a solution to growing wood demand across the region

Chapter 2 of the report presents the context of smallholder wood production systems in the region. While total wood demand across Asia and the Pacific remained constant between 1975 and 2015, this trend disguised a significant increase in industrial roundwood and a concurrent decline in fuelwood demand over this period. Looking ahead, primary processed wood product demand across Asia and the Pacific region is projected to increase by approximately 60 percent over the next 25 years, rising much faster than industrial roundwood production. Production from natural forests will likely decline further, while the rapid expansion of industrial plantations nears a peak.

These trends highlight the increasing importance of wood production in smallholder tree-farming systems, which have expanded in parallel with the expansion of industrial plantations. Though these systems lack a uniform definition and data, they provide the majority of roundwood production in several countries across the region. Such smallholder tree production systems can be classified along a gradient of increased commercialization and specialization, and include woodlots and small-scale plantations, intercropping and alley cropping, agrosilvopastoral and silvopastoral systems, homegardens, shaded systems and tree crop plantations, boundary plantings and sequential systems.

Barriers to smallholder wood production

Chapter 3 of the report presents barriers faced by smallholder wood production systems across the region, as well as effective strategies for overcoming them, based on the case studies presented in the second half of this report. To succeed, smallholder tree farmers need specific conditions to be met. Known as Byron's "Four Keys", these consist of clear ownership of trees, reliable markets, sympathetic legal and regulatory frameworks, and a robust package of technical options. However, the upscaling of smallholder wood production systems across Asia and the Pacific is currently obstructed by four clusters of barriers.

The first of these is lack of supportive policy, regulatory and institutional environments. Smallholder wood production often takes place within sectoral silos, constrained by incoherent sectoral policy frameworks and institutional divides. Insecurity of land and resource tenure effectively prevent investments by smallholders in longer-term land use, including in wood production systems.

Another important set of barriers comprises limited access to locally adapted and viable tree-farming technologies. Unsuitable design of these technologies as well as inappropriate species selection constrains smallholder wood production, impeding the full potential of these systems and jeopardizing the basis for production. In addition, inconsistent wood supply and low-quality timber frequently hinder access to larger markets.

The third cluster of barriers relates to limited infrastructure, market access and financial support. Here, inadequate transport infrastructure in remote locations, which also frequently suffer from structural constraints in the aftermath of armed conflicts, prevent smallholders from accessing markets. Fragmented markets further restrict wood production through increased transaction costs. Additionally, limited market knowledge and constrained access to information increase dependence on brokers, reducing the bargaining power of smallholders and ultimately the prices fetched for their products. Limited economies of scale also constitute a barrier, frequently excluding smallholders from accessing large international wood supply chains. Indeed, wood production systems are associated with increased investment costs and heightened risk profiles that smallholders are unable or unwilling to bear, while external investors rarely invest in such production systems due to their often informal character. Certification also constitutes an entry barrier to international markets, as the associated costs are prohibitive for smallholders and in many cases are not outweighed by their benefits.

The final cluster of barriers concerns weak technical capacities, collective organization and partnerships. The institutional divide between agriculture and forestry has left many countries lacking specialized extension services with expertise on knowledge transfer for smallholder wood production. Additionally, smallholders rarely organize as collectives, which prevents them from achieving economies of scale, enhanced knowledge transfer capabilities and increased bargaining power.

Effective strategies for overcoming barriers

Effective strategies for overcoming these barriers are demonstrated through context-specific innovations in smallholder wood production systems, presented in the regional case studies at the end of the report.

Policy, regulatory and institutional environment barriers may be overcome by dedicated policy and regulatory support for agroforestry and smallholder tree-farming. This can happen at different levels, including at the national policy level, integrating sectors in support of agroforestry and smallholder wood production, developing effective regulatory frameworks and easing regulatory constraints, including those hampering timber movement. Case study 1 on India's National Agroforestry Policy demonstrates how a dedicated, cross-sectoral policy can foster the development of smallholder wood production systems, resulting in 90 percent of the country's timber demand being met from smallholder tree production systems.

Supporting the reform of land and resource tenure is essential to promote tree-farming, as demonstrated by Case study 2 from Thailand. Here, farmers received support to improve their land and tenure security for teak trees planted on public land. They benefited from plantation registrations under the Forest Plantation Act and assistance to secure harvesting permits. The farmers also established collective logging groups, enhancing their knowledge of plantation management and negotiating fair, standardized prices for their timber.

Barriers to viable production technology can be overcome through the development of environmentally and economically viable models for smallholder wood production. These include woodlots relying on genetically improved planting stock of fast-growing species across the region. Case study 3 from Papua New Guinea exemplifies this approach, with provenance trials identifying superior individuals of teak and developed seed production, ensuring the availability of high-quality germplasm. Cost-effective nursery techniques were introduced to the region, enabling smallholders to establish 38 community nurseries with minimal capital investment. Trials were also conducted for sandalwood, using six seed sources and multiple host species to improve growth and enhance the commercial value of plantings. High-value germplasm was identified across five populations, with distinct oil and heartwood properties.

Matching species, varieties and genotypes to sites is equally essential to smallholder wood production. Improved management practices, optimization of site productivity, wood quality, growth rates and the management of pests are also of vital importance. This point is demonstrated in Case study 4 from Fiji, where the coconut rhinoceros beetle is responsible for the destruction of coconut plantations, and thrives in the decayed stumps and debris. In response to this threat, a project utilizing advanced wood-processing

technologies, such as spindleless lathe systems, converts low-value coconut stems into structural and architectural engineered wood products (EWPs) for both domestic and export markets. By turning stumps into a commercially viable resource, the initiative offsets the cost of replanting by creating a market-driven incentive for coconut stand renewal and the mitigation of pest outbreaks by reducing breeding grounds.

Barriers linked to inadequate infrastructure, market access and financial mechanisms can be overcome by investments in infrastructure, value addition and diversification of wood products to meet market demands, as well as livelihood integration and diversification. Investments in value addition are best illustrated by Case study 5 from Australia, where the Taylor family has restored their degraded farm, planting trees, adjusting grazing practices and investing in silvicultural operations and an on-site sawmill to convert low-value pulp logs into higher-value timber. This approach has significantly increased profitability while reducing reliance on external timber markets.

The benefits of livelihood integration and diversification are exemplified by Case study 6 from Japan. In Mizayaki Prefecture, the landscape-level Takachihogo-Shiibayama Mountainous Agriculture and Forestry System provides multiple products and services, including from agroforestry. Timber production is a major activity, with approximately 230 000 m^3 of Japanese cedar and Hinoki cypress harvested annually, much of it sold to national markets. Additionally, shitake mushrooms are grown on logs, making Morotsuka village within this landscape a global pioneer in sustainably certified shiitake mushroom cultivation.

Case study 7 from Viet Nam demonstrates the effectiveness of group certification and the collective organization of smallholders. The Binh Minh cooperative obtained FSC certification for their acacia plantations and engaged in a partnership with Hoa Phat, one of the largest timber processors in northern Viet Nam. This dual approach provided the cooperative with a stable market for their FSC-certified acacia timber and enabled investment in a cooperative-owned sawmill, increasing potential value addition. Further effective strategies include financial compensation for ecosystem services generated by smallholder tree-farming systems, including through Payment for Ecosystem Services schemes and the upgrading of financial services and instruments, such as subsidies or low-interest loans to overcome initial investment barriers by smallholders engaging in tree-farming. Carbon finance tailored to the needs of smallholders and collaborative investment models are also promising approaches.

Effective strategies to overcome lack of technical capacities, collective organization and limited partnerships include upgrading technical advisory services, increasing private sector engagement and linkages with businesses, and implementing effective community-based approaches and cooperative models. Investment in specialized extension services and dedicated training programmes represents a particularly effective strategy, as demonstrated by Case study 8 from Indonesia, where the smallholder teak agroforestry system in Gunungkidul is well integrated into the community's livelihood strategies. Here, trees serve as a "living savings account", selectively harvested to cover major expenses. Private sector engagement and linkages with businesses can facilitate value addition, access to markets and the overcoming of initial investment barriers (e.g. through contract farming to engage in wood production). Meanwhile, long-term partnerships and contracts stabilize prices and market linkages. Trust between community members and private sector actors is a prerequisite for success in such cases.

The importance of mutual benefits for all concerned is an essential prerequisite for smallholder wood production, as demonstrated by Case study 9 from Lao PDR. The Burapha agroforestry model involves the lease of degraded forest land for sequential agroforestry, providing opportunities to community members in terms of paid employment and intercropping of tree plantations with agricultural crops during the initial years. Engaging with the private sector can also effectively drive the expansion of smallholder tree-farming systems, as seen with eucalypt plantations in southern China.

Way forward: Scaling up agroforestry for wood production – the role of public policymakers

Chapter 4 of the report identifies seven strategic pathways public policymakers may pursue to support the advancement of smallholder wood production systems across Asia and the Pacific:

1. **Public policymakers can intensify efforts to strengthen enabling environments for smallholder tree-farming** through policy development, setting institutional responsibilities, institutionalizing land use planning and enhancing tenure resource security.

2. **The professionalization and empowerment of tree farmers** may be advanced through the development of networks and cooperative models for smallholder tree-farming, facilitating access to markets and information, creating financial incentives and easing access to credits.

3. **Producing data on smallholder tree-farming systems and their outputs** can improve recognition of the multiple contributions of these systems, help identify critical bottlenecks and source targeted support.

4. Though much has been achieved in recent decades, public policymakers should consider **further enhancing the selection and production of genetically adapted high-quality germplasm**. The improvement of planting material and the increased availability of improved planting stock are key priorities both of which remain unaddressed.

5. **The creation of innovative wood products and associated value chains** can be achieved by supporting the development of value chains and market access, the development of innovative products and public-private partnerships.

6. The timely **integration of high-value smallholder wood production into multifunctional land use systems** can be advanced by providing support to improved agroforestry design, incorporating wood products into smallholder livelihood strategies, and quantifying the environmental and climate benefits of smallholder wood production systems.

7. Finally, public policymakers are encouraged to reflect on the **creation of long-term models for sustainable, inclusive and resilient production**. Re-orienting tropical tree crop systems towards wood production as a secondary purpose, integrating smallholder tree-farming into landscape restoration programmes, and strengthening the resilience of smallholder tree-farming systems, are all strategies subordinate to the creation of such models.

Conclusion

Wood produced from smallholder tree-farming systems in Asia and the Pacific is a highly diverse and emerging source of timber that merits further attention and support. The strategies implemented and the lessons learned across the region, over decades of experimentation, can be built upon through continued institutional and technical support, and the implementation of new models for multifunctional tree-farming systems, capable of supporting greater incomes and stability for producers and their communities, and contributing to the resilience and sustainability of wider ecosystems.

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1 Background and objectives of the report

Trees are a widespread and important component of the diverse rural landscapes of Asia and the Pacific in which they play critical economic, social and environmental roles (FAO, 2019). Outside of forests, trees contribute significantly to meeting growing wood demand across the region, including within agroforestry systems[1] and small-scale planted forests, such as community plantations (henceforth referred to collectively as "smallholder tree-farming systems"). The importance of these systems in supplying wood is projected to rise in response to rapidly increasing wood demand in Asia and the Pacific and concurrent limitations in expanding wood production from natural forests and plantations. Aside from their important role in supplying wood, these systems are essential to conserving biodiversity, maintaining ecosystem resilience, providing ecosystem services and diversified livelihood opportunities in what are frequently disadvantaged areas, and contributing to food security. Table 1 provides an overview of these systems.

Table 1 Overview of smallholder tree-farming systems in rural landscapes of Asia and the Pacific[2]

Type	Examples
Trees outside forests on land predominantly under agricultural use	Trees scattered in mixed cropping systems; trees on pasturelands; trees in hedges; tree crops in monoculture plantations; trees in home gardens; trees in agroforests in the humid tropics; trees in shifting-cultivation areas; agroforestry parklands
Trees outside forests on land not predominantly under agricultural use	Small woodlands (<0.5 ha, <5 m height or <10 percent canopy cover); trees in narrow linear formations (e.g. plantings along roads, railways, canals, paddy fields); scattered trees around homesteads and villages, on community lands and in urban areas
Planted forests	Small-scale planted forests (including smallholder plantations)[3]

Source: Adapted from FAO (2019) and Arnold (2022).

Smallholder tree-farming systems encompass a wide range of products, practices and contexts and are shaped by a range of complex, interconnected drivers, including economic growth, urbanization, globalization, competing land uses and climate change (FAO, 2019). The degree of impact from these drivers varies across countries in the region.

Over the past 30 years, reforestation and the integration of trees into agricultural landscapes have experienced rapid growth in the Asia and the Pacific region, notably with the use of fast-growing species such as eucalypt, acacia, poplar and rubber (FAO, 2019), as well as sengon or gmelina, among others. This progress has been supported by sustained government initiatives as well as public and private investments.

1 Agroforestry is a collective term for land management systems where woody perennials are deliberately integrated spatially or temporally with agricultural crops and/or animals. For more information, see www.fao.org/agroforestry/en

2 These systems can be on private, communal or leased land.

3 Small-scale planted forests are defined by FAO (2009) as landholdings of an area "less than 100 ha, and greater than 0.5 ha", although definitions are largely context-specific and depend on the average landholding size in the country. For the purpose of the report, they explicitly exclude natural forests. Community forests, therefore, are not included within the scope of this report, unless representative of small-scale planted forests.

Exemplifying these achievements, in Viet Nam over 60 percent of industrial wood supply comes from plantations owned by smallholders with 1–5 hectares (ha) of land – areas that account cumulatively for 70 percent of the country's plantation area (Nambiar, 2021). In India, trees outside forests, largely owned and managed by smallholders, represent 36.2 percent of the country's combined tree and forest cover (Forest Survey of India, 2021) and constitute the most important share (64 percent) of fuelwood to meet growing national demand (Singh *et al*., 2021). Conversely, government forests in India account for less than 4 percent of total timber available for industrial purposes, while 90 percent of industrial requirements are met by agroforestry (Pandey and Roy, 2020).

Recognizing the critical role played by smallholder tree-farming systems in wood supply across the region and the wealth of knowledge and experience accumulated over past decades, the present review aims to analyse the characteristics of this supply, using illustrative examples from across the region, and take stock of needs with a view to promoting sustainable, productive and economically viable smallholder tree-farming systems. The three main objectives of the review are as follows:

1. Characterize smallholder tree-farming systems contributing to wood supply across Asia and the Pacific.
2. Identify enabling factors and strategies for enhancing wood supply from such systems, drawing on case studies.
3. Derive recommendations targeting policymakers to facilitate further upscaling of wood production from smallholder systems.

The overarching goal of this report is to support wood production from smallholder tree-farming systems, which constitute essential components of resilient, productive and sustainable agrifood systems. In so doing, the report responds to calls from FAO Member States in the Asia and the Pacific region, including those made during the 30th Session of the Asia-Pacific Forestry Commission (APFC), which recommended that FAO support efforts to "enhance the legality, sustainability, productivity and value added of wood … value chains, including in both domestic and international markets" (FAO, 2023).

The report aligns with global and regional frameworks, including the Sustainable Development Goals (SDGs) (notably SDG 15 "Life on Land", SDG 13 "Climate Action", SDG 1 "No Poverty" and SDG 2 "Zero Hunger"), FAO's Strategic Framework (particularly Better Production), the UN Decade on Ecosystem Restoration and the RESULT Asia-Pacific regional framework; and the Vision and Strategic Plan for ASEAN Cooperation in Food, Agriculture and Forestry 2016–2025, along with related instruments such as the ASEAN Guidelines for Agroforestry Development.

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2 Smallholders as key players in meeting growing wood demand

2.1 Booming demand for wood and wood products

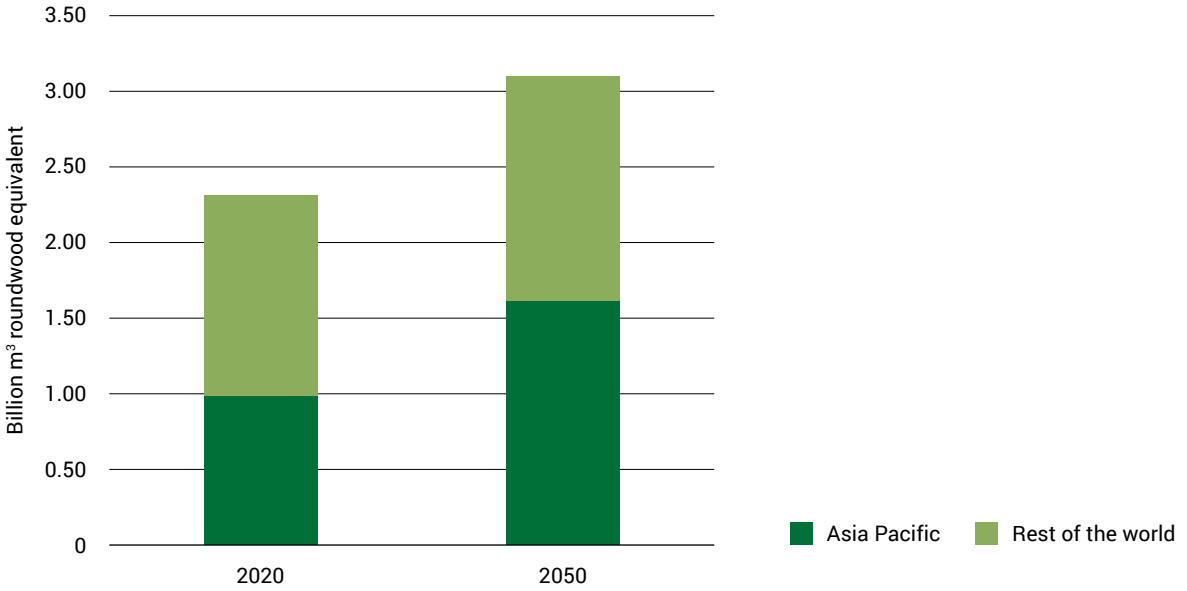
Asia and the Pacific is both a major producer and consumer of wood products, accounting for half of global wood consumption (FAO, 2019). Total roundwood production (industrial roundwood and woodfuel) averaged 1.14 billion m^3 per year between 2018 and 2023, having formerly reached 1.19 billion m^3 in 1990 (FAO, 2019). Consumption (defined as production plus imports minus exports) in the region remained stable at 1.15–1.2 billion m^3 per year between 1975 and 2017. The small gap in demand was evened out by global trade, averaging 45 million m^3 of annual imports into Asia and the Pacific (equivalent to 6 percent of total production volume) against 1.9 million m^3 of exports from Asia and the Pacific to the rest of the world (0.2 percent of total production volume) between 2018 and 2023 (FAO, 2025). However, stable production and consumption figures mask a marked increase in the share of industrial roundwood consumption from 22 percent to 41 percent between 1975 and 2017 (FAO, 2019). The share of woodfuel consistently declined over the same period, although a significant proportion of roundwood produced in the region is still consumed nationally as woodfuel (FAO, 2019). Indeed, the increase in industrial roundwood consumption over the past 30 years confirms the rapid development of wood-based value chains in the region.

By 2050, the need for wood and other forest products in the Asia and the Pacific region will rise substantially, with the population expected to increase from its current level of 4.7 billion to 5.2 billion (ESCAP, 2023). The utilization of wood products will be fuelled by this growing population coupled with rising incomes in developing regions, leading to increased demand for consumer products and intensified construction activities. The highest demand for wood products is expected in emerging markets, while global projections indicate that the consumption of primary processed wood products is likely to increase 35 percent by 2050 (FAO, 2022a). Eastern Asia alone could account for 41 percent of global consumption (FAO, 2022a). Assuming a 20 percent increase in mass timber construction for new urban housing in 2050, sawnwood, plywood and veneer consumption volumes will grow by 26 percent in South Asia. Rising demand for industrial roundwood and simultaneous shortages in Asian sub regions will trigger increasing trade flows of industrial roundwood and primary processed wood products (see Figure 1 and Figure 2).

2.2 Expansion of planted forests and tree assets across Asia and the Pacific

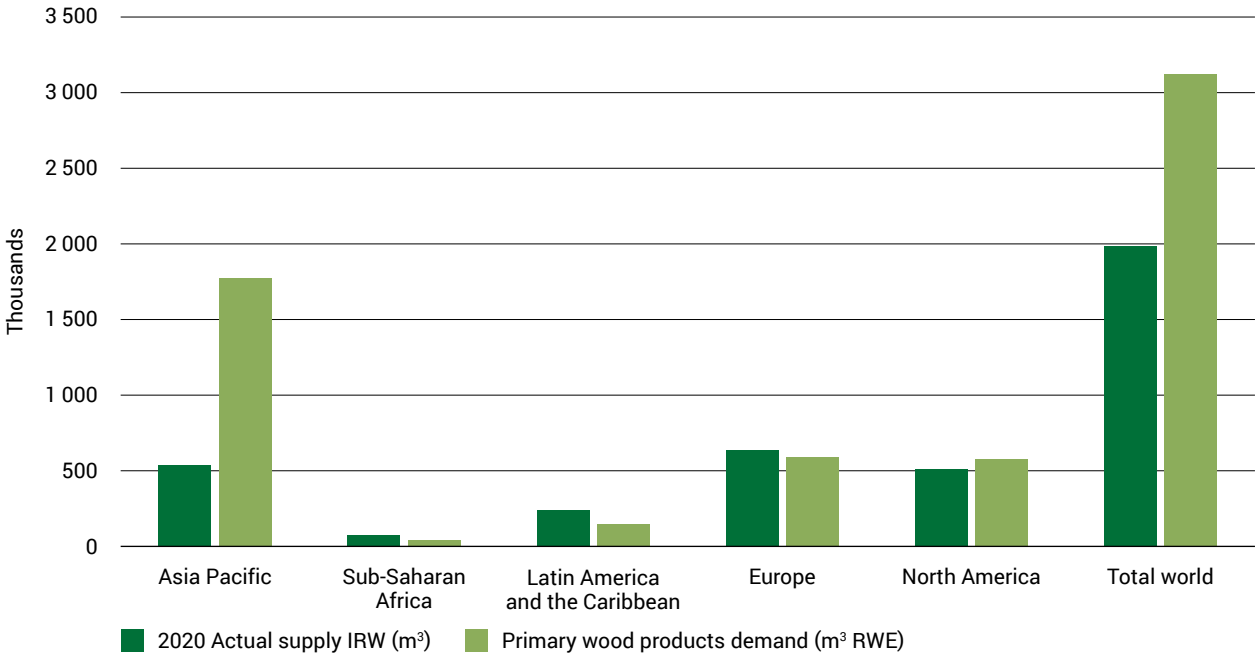
The significance of the Asia and the Pacific region in meeting increasing global wood demand is underscored by its 68 percent share in global roundwood production. In fact, five out of the six countries dominating tropical roundwood production globally are in Asia: Indonesia (with a share of 30 percent by volume in 2020), India (18 percent), Viet Nam (12 percent), Thailand (4 percent) and Malaysia (4 percent). While some countries, such as Malaysia, show declining trends, others including Indonesia and Viet Nam have increased production volumes over time (Maplesden, 2024).

Figure 1 Regional share in global consumption of primary processed wood products, 2020–2050



Source: Adapted from FAO, 2022a.

Figure 2 Actual production and projected demand by 2050 of industrial roundwood by world region



Source: Adapted from FAO, 2022a.

Globally, rising wood demand has prompted the intensified management of natural production forests. However, this process is limited by the productive capacities and other priority functions of natural forests. Factors including the lower productivity of overlogged natural forests, logging bans in natural forests and the enactment of protected areas, conducive policy environments and large investments in plantation forestry, have resulted in a shift of wood supply from natural towards planted forests (FAO, 2019).

Table 2 Ten main contributors to absolute expansion of planted forest cover, 1990–2020

	Planted forest (1 000 ha)		Total forest area (1 000 ha)	
Countries by rank	1990	2020	1990	2020
1. China	**44 152**	**84 696**	**157 141**	**219 978**
2. Canada	4 618	18 163	348 273	346 928
3. United States of America	17 938	27 521	302 450	309 795
4. Brazil	3 558	11 224	588 898	496 620
5. India	**5 715**	**13 269**	**63 938**	**72 160**
6. Russian Federation	12 651	18 880	808 950	815 312
7. Sweden	8 089	13 912	28 063	27 980
8. Indonesia	**145**	**4 526**	**118 545**	**92 133**
9. Viet Nam	**745**	**4 349**	**9 376**	**14 643**
10. Finland	4 390	7 368	21 875	22 409

Note: Countries from Asia and the Pacific are highlighted in bold.
Source: https://fra-data.fao.org/assessments/fra/2020 (includes rubber).

This shift triggered an expansion of planted forests by 63 million ha between 1990 and 2020 in Asia and the Pacific, representing half of the global increase in forest plantation during this period. Planted forests encompass a wide range of purposes, management intensities and objectives, species, rotation lengths, end uses (e.g. timber, non-timber products, pulp, bioenergy), scale of operations and ownership (Baral, Guariguata and Keenan, 2016). Of the 11 countries responsible for 81 percent of the increase in global planted forest area between 1990 and 2020, four are in the Asia and the Pacific region, namely China, India, Indonesia and Viet Nam (FAO, 2020a) (see Table 2).

In these countries, smallholders have contributed significantly to planted forest area expansion. For example, in Viet Nam, expansion of planted forests has grown from 219 000 ha in 1975 to 4.24 million ha in 2018, with smallholders managing over 1.9 million ha, including approximately 1.7 million ha of the country's 2.2 million ha of acacia plantations (Midgley *et al.*, 2021). As a result, planted forest area in Asia and the Pacific doubled between 1990 and 2015 (FAO, 2019), and today accounts for more than 20 percent of forests in the region (FAO, 2020b). Of the estimated 294 million ha of planted forests worldwide in 2020, China has by far the largest area with about 85 million ha (29 percent of the global share).

However, the rate of new planted forest establishment in the Asia and the Pacific region slowed over the period 2010–2015 (FAO, 2019). Future expansion faces limitations including challenges related to land tenure, competing land use priorities, limited land availability and various social constraints (Barua, Lehtonen and Pahkasalo, 2014). In Southeast Asia, in particular, population pressure and land tenure arrangements will challenge large-scale plantation establishment (Phimmavong *et al.*, 2019). Other key obstacles include economic viability, productivity and the necessary investments for planted forests (FAO, 2019).

2.3 Growing significance of wood from smallholder tree-farming systems

The growing constraints on expanding planted forests across Asia and the Pacific underscore the need to explore new, sustainable ways to increase roundwood supply without impacting current land use. While industrial wood markets have historically overlooked smallholder tree-farming, these systems are now increasingly recognized as strategic sources of wood supply (Byerlee, 2014; FAO, 2019; Roshetko *et al.*, 2013).

Although the extent of smallholder wood resources in Asia has not been quantified (Midgley, Stevens and Arnold, 2017), smallholder tree plantations have considerably expanded the production base of wood over the past 30 years in Asia, driven by market demand, diversification of livelihood strategies, increased incomes (Jayathilake *et al.*, 2023), as well as urbanization and labour shortages. Recent data on smallholder eucalypt and acacia plantations in a number of countries across the region illustrate their contribution to wood supply (see Table 3). In China, India, Indonesia, Viet Nam, Malaysia and the Philippines, smallholder tree-farming accounts for a significant proportion of regional wood supply. In the Lower Mekong Subregion, comprising Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam, acacia and eucalypts tree plantations, particularly those managed by smallholders and within agroforestry systems, are emerging as the primary source of wood, estimated at over 86 million m^3 annually (Arnold *et al.*, 2022).

The most successful systems depend on species well-suited to local site conditions, which maximize both growth and yield (Baral, Leksono and Seol, 2022), and are linked to strong market demand for specific products, such as furniture, veneers, and wood fibre for pulp and panels. Expanding veneer production from small-dimension eucalypt wood in southern China (Arnold *et al.*, 2020) and the production of wood chips and furniture from acacia in Viet Nam demonstrate how under stable, fair prices and reliable demand, smallholders are more likely to invest in tree planting (see Box 1 for examples).

Table 3 Estimated areas and wood volumes of eucalypts and acacias grown by smallholders, selected countries

Country	Area of smallholder-grown eucalypts and acacias		Annual wood production from smallholder eucalypts and acacias	
India	Eucalypts	≈ 5 million ha	Eucalypts	≈ 25 million m^3
	Acacias	Uncertain	Acacias	Uncertain
China	Eucalypts	≈ 2 million ha	Eucalypts	≈ 27 million m^3
	Acacias	20 000 + ha	Acacias	Uncertain
Viet Nam	Eucalypts	≈ 0.24 million ha	Eucalypts	≈ 0.4 million m^3
	Acacias	1.7 million ha	Acacias	≥ 23 million m^3
Sri Lanka	Eucalypts	≈ 20 000 + ha	Eucalypts	≈ 0.3 million m^3
	Acacias	Uncertain	Acacias	Minor
Thailand	Eucalypts	≈ 0.8 million ha	Eucalypts	≈ 10 million m^3
	Acacias	Uncertain	Acacias	Uncertain
Total	**Eucalypts**	**≈ 8 million ha**	**Eucalypts**	**63 million m^3**
	Acacias	**1.7 + million ha**	**Acacias**	**23 + million m^3**

Source: Adapted from FAO (2019) and Arnold (2022).

Box 1 Examples of smallholder tree-farming across Asia and the Pacific

- In **Lao PDR**, the Land Forest Allocation Programme (LFAP), initiated in the 1990s, allocated small parcels of land of around 1 ha to smallholders. The resulting agroforestry system consists of teak plantations producing high-value timber, integrated with other subsistence and commercial land-use activities. However, the overall plantation area for teak is relatively small compared to other species (Keenan, 2019).
- In **India**, 80 percent of wood for pulp, paper, veneer and wood panels is produced on farms, primarily from eucalypts, acacias, poplars, casuarina and leucaena (Midgley, Stevens and Arnold, 2017). Today, 90 percent of industrial requirements are met by the agroforestry sector (Pandey and Roy, 2020).
- In **Indonesia**, approximately 3.1 million ha of agroforestry systems, including smallholder plantations, composed of teak, albizia, mahogany, neem, sandalwood and eucalypts supply wood, primarily to the furniture and veneer industries on Java (Midgley, Stevens and Arnold, 2017).
- More than 95 percent of **Thailand**'s 700 000 ha of eucalypt plantations are privately owned, partially through contract farming arrangements involving smallholders. The expansion of smallholder plantations has been promoted by commercial companies (e.g. SCG, Double A) on agricultural land, including rice berms and along irrigation canals (Midgley, Stevens and Arnold, 2017).
- In **Viet Nam**, government investment programmes have supported dynamic growth in plantation areas in response to rapid decline in forest cover. Under the Forest Land Allocation programme, over 1.6 million ha of plantations are now managed by smallholder growers. Largely supplied with acacia wood from these smallholder plantations, Viet Nam has become the largest hardwood woodchip exporter and the fourth largest furniture exporter globally (Midgley, Stevens and Arnold, 2017). Under these conditions, plantations have become highly profitable for smallholders, with an Internal Rate of Return above 20 percent for short rotation acacia for woodchips in Central Viet Nam and above 30 percent for longer rotations, with carbon finance offering the potential to further improve profitability (Keenan, 2019).
- In **China**, the Grain for Green programme, introduced in 1999, has focused on tackling both land restoration and rural poverty. An integral part of the programme was fundamental policy reforms regarding payments for environmental services and fiscal transfers. By 2010, the programme encompassed more than 15 million ha in 20 provinces, involving 30 million rural households (Buttoud *et al.*, 2013). In Guanxi province alone, eucalypt plantations now cover 2 million ha of which 200 000 are managed by multinational companies. The expansion of smallholder eucalypt plantations was further fuelled by the significant growth in veneer and plywood industries established for the production of small-diameter logs. These smallholder tree-farming systems have therefore played an instrumental role in transforming the wood-based industries of the entire region.
- In the **Philippines**, the largest proportion of log production came from planted forests, mostly established by smallholders. In a region of northern Mindanao, 135 small-scale sawmills exclusively supplied with farm-grown timber had a sawn timber production potential of 76 596 m^3 per year (Bertomeu, 2008).

Smallholder tree-farming systems have the potential to supply additional industrial roundwood and wood fuel from palm oil and rubber plantations (Bissonnette and De Koninck, 2017) as well as from restored landscapes. In addition to meeting wood demand, these systems contribute to reducing vulnerability and delivering net livelihood benefits for small producers (Flanagan *et al.*, 2019).

Compared to community-owned natural forests, smallholder tree-farming systems offer several commercial advantages, including better access to infrastructure and markets, clearer property rights, higher land productivity, enhanced management and monitoring capacity, access to labour, and experience in intensive production and marketing (Scherr, 2004). These systems are also well-suited to supply both domestic markets for small-scale farm wood products (Scherr, 2004) and large-scale domestic and regional commercial wood enterprises.

However, the increased integration of trees into agricultural landscapes will require targeted incentives and strategic investments, including specialized technical support, market access and enabling policy environments. These measures can unlock the full potential of smallholder systems (Baral *et al.*, 2021), enhance their productivity (Flanagan *et al.*, 2019; Midgley, Stevens and Arnold, 2017), support their integration into wood supply chains across the region (Flanagan *et al.*, 2019), and ultimately contribute to both restoration and increased production objectives (FAO, 2022b).

2.4 Characterizing the variety of smallholder tree-farming systems

2.4.1 Diversity of smallholder tree-farming systems

Smallholder tree-farming systems in the Asia and the Pacific region are diverse (see Table 1) and exhibit varying degrees of specialization in terms of wood production. Highly specialized systems, such as smallholder woodlots and plantations, focus on producing a limited range of high-volume products, while integrated systems such as alley cropping and home gardens deliver a more diverse bundle of products and services which enhance food security and economic resilience and provide various co-benefits. For example, in Viet Nam, the acacia plantation boom is driven by hundreds of thousands of smallholders producing for profit (Kull *et al*., 2024). At the opposite end of the spectrum, communities in Northeast India practising shifting cultivation utilize wood to a significant extent for subsistence.

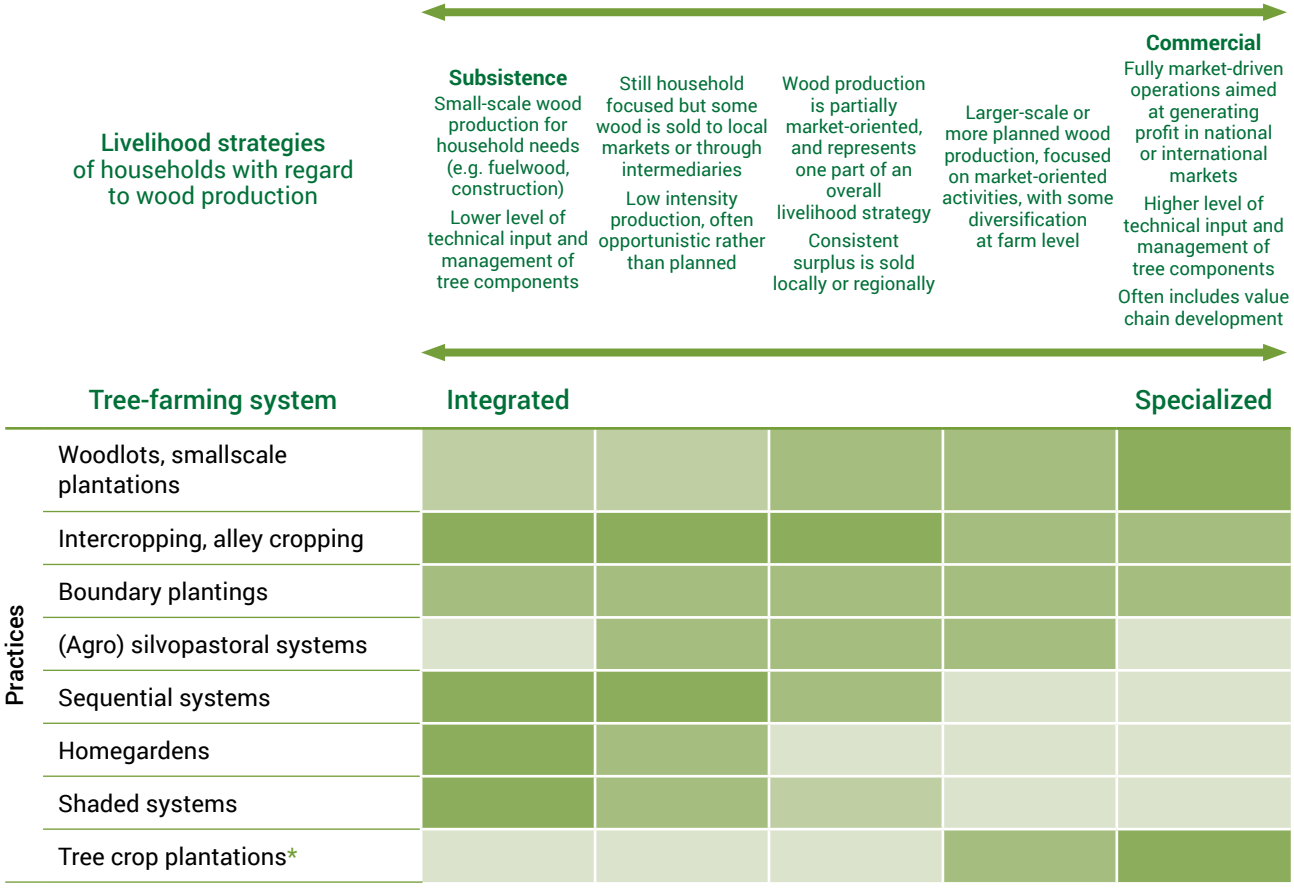
These smallholder systems supply a wide array of wood products, including fuelwood, wood chips, sawn timber, furniture, panels and poles, depending on the extent of local value addition (see Chapter 7 on wood products). These products come from a diversity of tree species across the region, notably eucalypts (*Eucalyptus* spp.), acacias (*Acacia* spp.) and teak *(Tectona grandis)*, which are planted extensively for timber and other wood products (see Chapter 8 on common species). Woodlots are established predominantly as single-species plantations, often using such fast-growing exotic species. This preference is driven largely by the need for quick economic returns, as these species mature faster, are generally more resistant to herbivores, and provide higher yields in a shorter timeframe compared to native or mixed-species systems. At the same time, mixed-species plantations have been established through restoration initiatives, as on Leyte Island in the Philippines (Dinh Le *et al*., 2020). Agroforestry systems are more likely to include native tree species, often co-existing with fast-growing trees, fruit trees and cash crops (FAO, 2019).

Wood production in these systems can be viewed along a spectrum – ranging from subsistence-level activities to fully commercial operations. This range reflects variations in purpose, management intensity, market orientation and value chain development (see Figure 3). The highest levels of specialization tend to be observed as a result of the separation and industrialization of agriculture and forestry developments that frequently (though not always) come at the expense of more integrated land-use systems (Pichler, Bhan and Gingrich, 2021). While no quantified comparisons exist, systems can be broadly categorized by increasing emphasis on wood production as follows: 1) agroforestry systems where wood production is a co-benefit, 2) agroforestry systems where wood production is a primary objective, and 3) dedicated smallholder woodlots or small-scale tree plantations.

At the subsistence end, wood production is focused primarily on meeting household needs, such as fuelwood or construction materials. Such production systems are characterized typically by minimal technical input and tree management, particularly when producing fuelwood. Trees are integrated into the broader agricultural landscape as part of diversified livelihood strategies, with little emphasis on market engagement. For example, in agrosilvopastoral systems of the lower Himalayas in India, smallholders rely on agroforestry trees as their primary source of fuelwood and fodder (Nagar *et al*., 2022). As production shifts towards market orientation, systems begin to exhibit more deliberate planning and management in the area of wood production. Farmers may allocate a portion of their wood production for sale in local or regional markets, transitioning from purely household use to market-linked activities, as in the teak agroforestry systems in Gunungkidul, Indonesia (see Case study 8). This middle range of the spectrum balances subsistence needs with income generation, often using low to moderate levels of technical input and labour for tree management and harvesting.

At the commercial end, wood production becomes fully market-driven with the goal of generating profit. These systems are often larger in production scale, rely on advanced technical inputs and management practices, and target high-value national and international markets. Farmers and communities involved in commercial systems at times engage in value adding to maximize profitability. Examples include dedicated woodlots or smallholder plantations, such as acacia plantations in Viet Nam and intensively managed agroforestry systems.

Figure 3 Tree-growing practices adopted according to the importance of wood production in smallholders' livelihood strategies


Livelihood strategies of households with regard to wood production
Subsistence
Small-scale wood production for household needs (e.g. fuelwood, construction)
Lower level of technical input and management of tree components
Still household focused but some wood is sold to local markets or through intermediaries
Low intensity production, often opportunistic rather than planned
Wood production is partially market-oriented, and represents one part of an overall livelihood strategy
Consistent surplus is sold locally or regionally
Larger-scale or more planned wood production, focused on market-oriented activities, with some diversification at farm level
Commercial
Fully market-driven operations aimed at generating profit in national or international markets
Higher level of technical input and management of tree components
Often includes value chain development
Tree-farming system
Integrated
Specialized
Practices
Woodlots, smallscale plantations
Intercropping, alley cropping
Boundary plantings
(Agro) silvopastoral systems
Sequential systems
Homegardens
Shaded systems
Tree crop plantations*
Rarely found
May happen in specific settings
Often found
Highest degree of occurrence

* Refers to commercial commodity production systems (e.g. mango, rubber, cashew) primarily oriented towards non-wood products. The potential exists for wood components to be utilized at the end of the tree's productive life, though it is not always managed or harvested with commercial intent.

Note: Shading indicates the typical alignment of different agroforestry systems along the spectrum of wood production intensity.

Source: Authors' elaboration.

The progression along this spectrum is influenced by factors such as market access, technical knowledge, land tenure and policy support. Although different types of smallholder tree-farming systems – whether home gardens, alley cropping or woodlots – can operate at any point along this spectrum, regional trends indicate that certain systems are more commonly associated with certain levels of wood production intensity. This alignment is influenced by the goals and resources of the producers, as well as the inherent characteristics of different systems. For example, home gardens and boundary plantings are more commonly associated with subsistence production, while woodlots often dominate the commercial end of the spectrum, where higher levels of specialization and market engagement are feasible.

2.4.2 System typology

The types of systems along this spectrum vary in their design, level of integration and components – ranging from intensive timber production to multifunctional agroforestry systems that combine trees with crops and livestock. Indeed, many of these systems can be considered as forms of agroforestry, offering a suite of products and services beyond wood production. They can be broadly categorized and described as follows.

Figure 4 Diverse smallholder tree-farming systems in the landscape

Source: Authors' elaboration.

Woodlots and small-scale plantations (individual and community plantations)

Smallholder plantations are of major significance for regional wood supply. Indeed, wood production is the principal focus of these plantations and woodlots – at times loosely integrated with agricultural production at the farm level – as well as of community-based forestry models. For example, in Thailand, smallholders cultivate eucalypt in boundary plantings around rice paddies and on over 900 000 ha of mainly private plantations. Meanwhile, Lao PDR has an estimated 67 000 ha of eucalypt and 25 000 ha of teak smallholder plantations. Such plantations are frequently established on degraded land or land marginally suitable for agricultural production, and utilize fast-growing and high biomass-yielding species such as eucalypts and acacias. These species help restore degraded land and provide a sustainable supply of wood for a variety of purposes (Brady *et al.*, 2023). For example, in Viet Nam, the Binh Minh Agroforestry Cooperative, which started as a small group of acacia growers, now collectively manages 60 ha of FSC-certified acacia plantations (see Case study 7). Through community-based plantation forestry initiatives in countries like Bhutan, Indonesia and Nepal, local communities establish and manage community forests for timber, firewood and non-timber products, often alongside food crops.

Intercropping and alley cropping

Many agroforestry systems focus primarily on agricultural crops and non-wood forest products (NWFPs), with wood production of secondary importance. Such systems provide multiple products including wood, fruits and other NWFPs. Intercropping allows farmers to continue producing food and generating income throughout the year, while establishing tree crops and diversifying income streams (FAO, 2019; van Noordwijk, 2019) if linked to additional markets. For example, in southern China, India, Indonesia,

the Philippines, Thailand and Viet Nam, smallholder farmers temporally or spatially integrate commercial timber species such as teak *(Tectona grandis)*, acacia (*Acacia mangium, A. auriculiformis* and their hybrids), mahogany and eucalypts into their farming systems, frequently in combination with fruit trees (e.g. coffee, cacao and citrus). In the Philippines, a mix of fast-growing trees (e.g. *Gmelina arborea)* grown for timber and fuelwood are planted along with fruit trees and agricultural crops for local markets (van Noordwijk, 2019). Farmers often intercrop trees with annual crops like rice and maize during the early-growth stages of the trees. This can be observed in the sengon *(Falcataria falcata)* agroforestry system practised in Pati, Central Java, Indonesia, where smallholders cultivate sengon intercropped with rice and cassava. In the Xepon district of Savannakhet Province, Lao PDR, yang bong *(Persea kurzii)* trees are intercropped with rice and bananas, allowing smallholders to benefit from the sale of both timber and NWFPs, alongside agricultural products such as bananas (Keenan, 2019).

Agrosilvopastoral and silvopastoral systems

Agrosilvopastoral and silvopastoral systems integrate trees with animal production. While silvopastoral systems combine trees and livestock, agrosilvopastoral systems include a third component – agricultural crops. These systems have deep historical roots, with livestock, such as cattle, goats and sheep, traditionally grazing on tree fodder and pastures in wooded rangelands.

A notable example of a silvopastoral system is livestock grazing within plantation forests, as practised in New Zealand, where livestock benefits from the shade and forage provided by trees. Similarly, at Taylors Run Farm in Australia (see Case study 5), silvopastoral practices integrate Radiata pines and sheep in a way that enhances animal productivity while maintaining ecological balance. Wooded pastures or grazed woodlands typically feature a lower tree density than conventional forests. Livestock can directly browse on trees or farmers may employ a cut-and-carry system to supply fodder to animals.

Home gardens

Home gardens are small, intensively managed agroforestry systems located around homesteads, distinguished by their diverse, multi-strata composition of woody species, crops and sometimes livestock. Home gardens play a particularly significant role in the Asia and the Pacific region, where they function as a cornerstone of traditional farming systems, deeply embedded in local cultures and livelihoods, and are central to local and national wood supply. Farmers in countries such as India, Indonesia, the Philippines and Sri Lanka have long relied on home gardens for food security, income generation and multifunctionality, often combining fruit and nut trees, medicinal plants, vegetables, fodder and timber species, and small-scale livestock or poultry on a single plot. For example, *Pekarangan* home gardens in Gunungkidul, Indonesia (see Case study 8) are dominated by tree species, including teak, with crops growing in the understory. The Kandayan home gardens in Sri Lanka are also used to grow food crops, medicinal plants, fruit trees and timber species (Mattsson, Ostwald and Nissanka, 2018).

Shaded systems and tree crop plantations

Shaded systems are generally designed to grow shade-tolerant crops, such as coffee, tea or cocoa, under the canopy of multi-purpose tree species. These systems are particularly suited to tropical and sub-tropical areas in the region, where they can mimic natural forest ecosystems in structure and function. Although these systems are generally focused on producing understory crops rather than wood, in some instances the shade trees may still provide timber, fuelwood or fodder. For example, in shaded coffee systems in West Lampung, Indonesia, high-value shade trees such as *Shorea javanica* and *Michelia champaca* are integrated into plantations for their wood (Evizal *et al*., 2016). In Sri Lanka, Grevillea robusta is commonly associated with tea plantations.

Tree crop plantations

Tropical tree crops, such as rubber, fruit and nuts trees (e.g. cashew) or coconut, offer the potential to supply wood or wood-like properties materials. Tree crops can be managed for both crop production and wood supply, creating a dual-purpose land use system that contributes to industrial roundwood markets.

This model is particularly important in Southeast Asia (FAO, 2022a) where cashew, coffee, eucalyptus, sugarcane and fruit trees have undergone rapid expansion in recent decades (Hurni and Fox, 2018). Over 7 million have been planted with rubber, including 320 000 ha in Lao PDR (FAO, 2019; Keenan, 2019). In 2014, these "boom crops" occupied 18 percent of the combined land area of Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam (Hurni and Fox, 2018). Rubberwood is a by-product of the rubber industry, harvested at the end of the rubber tree's latex production cycle, and offers an economically viable source of timber for plywood, furniture and other industries (FAO, 2022a). Meanwhile, Indonesia is the third-largest mango producer worldwide over 1994–2023 with harvested areas estimated at close to 300 000 ha in 2023 (FAO, 2025). Tree crops are grown on large plantations in all these countries; however, smallholder farmers also own and manage a sizeable portion of the area cultivated under these species.

Boundary plantings

Boundary plantings are linear rows of trees or shrubs established along field edges, between farms, and near infrastructure such as roads or long water bodies. These plantations mark boundaries, provide living fences, serve as shelter or windbreaks, and act as buffers between different land uses. They often include species selected for their ability to provide timber, fruits, fuelwood or fodder, while also fulfilling protective roles, such as reducing wind speed, controlling soil erosion, or protecting crops and structures. In Gunungkidul, Indonesia, for example, teak is grown along the border of irrigated rice and other cropping systems, while in Khan Na, northeastern Thailand, Double A eucalypt boundary plantings are used by 1.5 million contract farmers.

Sequential systems

Shifting cultivation and sequential agroforestry systems in the region can take many forms, some of which contribute to wood production. Shifting cultivation systems typically involve the rotation of agricultural activities across multiple parcels of land, alternating cultivation with fallow periods to allow soil fertility and vegetation to regenerate, occasionally with the integration of tree crops during fallow phases. For example, the Takachihogo-Shiibayama composite agroforestry system in Japan utilizes shifting cultivation involving small plots of buckwheat, millet and legumes cultivated in cycles, followed by 20–30 years of fallow for forest regeneration (see Case study 6). Sequential agroforestry systems, such as *taungya*, focus on a single plot, where food or cash crops are initially intercropped with trees, transitioning over time to tree-dominated production as the trees mature. Both approaches rely on sequential land use but differ in their spatial and cyclical use versus temporal and transitional use. However, these approaches can be combined, as seen in the case of *Jhum* (see Box 2), where shifting cultivation incorporates temporal transitions during fallow phases to promote forest regeneration and tree-based benefits.

Box 2 Jhum rotational cultivation

Jhum, or rotational cultivation, is an ancient temporal agroforestry system practised across northeast India, adjacent parts of Bangladesh and Myanmar. Though substantial variations exist, communally managed land is generally divided into plots that can sustain the community with sufficient agricultural produce for one to two years. Trees are harvested and plots are burnt on an annual rotation cycle, followed by cultivation with diverse vegetables and upland rice. Cultivation continues for one to two years before plots are abandoned to forest succession, and the community moves on to cultivate subsequent plots, until the rotation once again closes the loop between 3 to 20 years later. Early successional plots are important sources of NWFPs, while the wood harvested from *jhum* is an important source of cash income for farmers in many areas and is frequently processed into charcoal on site.

In the *taungya* system in northern Laos, teak *(Tectona grandis)* is intercropped with rice or maize during the first two years on plots commonly 1 ha in size. When establishing woodlots, this system allows smallholder farmers to maintain food production and diversify their income (Race and Wettenhall, 2024). Though manual weed control becomes challenging after the initial two years, this model is considered viable due to the high market price of teak offered to smallholders by traders or sawmills (Carias *et al*., 2022). Similarly, in India, smallholder farmers grow teak trees alongside agricultural crops, such as legumes and vegetables, during the early years of tree growth. The teak is harvested for high-value timber, providing a significant source of income for farmers (Perdana, Roshetko and Kurniawan, 2012).

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3 Enhancing wood production from smallholder tree-farming systems

3.1 Barriers to smallholder tree-farming

Barriers to the expansion of smallholder tree-farming have been widely studied. For smallholder tree-farmers to succeed, four conditions identified by Neil Byron (2001) should be present. These "Four Keys" are: 1) clear ownership of trees; 2) reliable markets; 3) sympathetic legal and regulatory frameworks; and 4) a robust package of technical options. While these recommendations are 25 years old, they remain valid. Reliable value chains and risk mitigation are important issues, and severe impediments to any of the "Four Keys" jeopardize the efficiency and effectiveness of the forest product value chain, the livelihoods and financial sustainability of the smallholder tree-farmers, and their substantial contributions to national productivity and forest assets. Building on these "Four Keys", this section explores the barriers that currently constrain the expansion of these systems.

3.1.1 Lack of supportive policy, regulatory and institutional environments

Policy, legal, regulatory and institutional framework gaps

Growing competition for agricultural land driven by population growth, increasing food demand, higher economic returns, market demand for global commodities, agriculture policies favouring monocultures and the expansion of irrigation infrastructure, and land tenure issues, may encourage a shift from traditional agroforestry systems towards intensive agriculture (Park, Baral and Shin, 2022). The expansion of smallholder forestry requires balancing tree crops with agriculture, however competition for land frequently constrains this potential (FAO, 2022a). The historical divide between land-based production sectors – primarily agriculture and forestry – has reduced the scope for integrated land use (Springgay and Pajel, 2024). Moreover, the absence of integrated land use planning, based on consensus built across stakeholders, means that conflicting sectoral priorities are not reconciled at different spatial and governance scales, with the allocation of land to different uses failing to respond to the needs of society at large.

Sectoral policies for agriculture and forestry typically operate in silos, which can cut across commodities or species. As an example, rubber is typically treated as an agricultural commodity but is included as "forest cover" in national statistics and represents a major source of wood. Agricultural policies often focus on maximizing monoculture production, with aligned incentives, credits and price supports (Buttoud *et al.*, 2013). Meanwhile, forestry policies tend to emphasize conservation on the one hand and large-scale production on the other, while frequently restricting the harvesting of native trees from plantations. These rigid frameworks often fail to accommodate the specific needs of smallholders, including their distinct capacities and risk profiles (Flanagan *et al.*, 2019). In Viet Nam, for example, policies promote longer timber rotations for international furniture markets while incentives for smallholders may not comprehensively bear the added risks and investments (Flanagan *et al.*, 2019).

Legal restrictions on multifunctional land management and associated policies further discourage or even penalize smallholder tree planting on agricultural land in several countries. Though largely unconstrained by the social problems associated with large plantations, the development of smallholder plantations may be restricted by environmental challenges, which include deforestation (Chen *et al*., 2024).

Finally, bureaucratic regulations are often sector-specific and incompatible with smallholder tree-farming, complicating the issuance of land use certificates and approval for tree harvesting or movement, as seen in Lao PDR (Le *et al*., 2022).

Land and resource tenure issues

Tree-farming, unlike annual cropping systems, requires longer-term investments, necessitating a higher degree of land tenure security. However, in many countries across the region, land tenure is often unclear, insecure, and characterized by contradictions between customary and statutory systems, with tenure durations often too short to encourage long-term tree-farming and agroforestry practices (Baral, Leksono and Seol, 2022; Springgay and Pajel, 2024; van Noordwijk, 2019). For example in Lao PDR, land leases are often short, limiting farmers' ability to plan for long-term land use (Le *et al*., 2022). Similarly, insecure land tenure discourages private investments in tree planting, while concerns over land rights and livelihoods lead local communities to resist foreign investments (Phimmavong *et al*., 2019). In contexts where customary land tenure is recognized (e.g. Papua New Guinea, Pacific nations and certain states of northeast India), the need for formal tenure security may be less critical. Additionally, tenure over land does not always extend to tenure over trees, and insecure land and resource tenure is frequently compounded by gender imbalances (Buttoud *et al*., 2013). Without clear and undisputed rights to harvest and sell timber, including for commercial purposes, smallholders are unlikely to invest in tree planting and management (Carias *et al*., 2022; FAO, 2022c; IFC Manufacturing Agribusiness and Services, 2018; Le *et al*., 2022).

3.1.2 Limited access to locally adapted and viable tree-farming technologies

Unsuitable system design and species selection

The design of agroforestry and smallholder woodlot systems often suffers from inappropriate species selection (Catacutan *et al*., 2017), limited access to quality propagation materials (seeds and seedlings), poor spatial arrangements of trees and agricultural crops (Park, Baral and Shin, 2022), and a lack of consideration of farmers' needs (Shukla and Dhyani, 2023). The frequent reliance on monocultures in both smallholder tree plantations and agroforestry systems (Shin *et al*., 2020), as well as the lack of functional diversity (Ha *et al*., 2024), also undermine productivity and sustainability. As an example, rubber intercropping systems in Southeast Asia on high productivity sites require adequate spacing to avoid early competition for sunlight (Catacutan *et al*., 2017). Poorly designed systems and poor management lead to reduced productivity (Ha *et al*., 2024), decreased smallholder income (Ullah, Mishra and Bavorova, 2023), increased erosion and land use change (Park, Baral and Shin, 2022).

Variable wood quality and supply

While smallholder tree-farming has the potential to contribute significantly to local wood supplies, the quality and consistency of timber from these systems is often inadequate. Variability arises from differences in species, growing conditions, management practices and lack of coordinated aggregation of produce. This is evident particularly in the case of rubberwood and other tree species grown in agroforestry systems primarily for reasons other than timber, where inconsistent quality limits their suitability for modern industries that require reliable, high-quality raw materials (FAO, 2022a). For instance, in Viet Nam, smallholders frequently harvest acacia plantations on short rotations (4–6 years) to meet demand for industry and immediate financial needs. This practice produces lower-quality wood, which is less suitable for value-added processing and high-demand markets (Carias *et al*., 2022).

3.1.3 Limited infrastructure, market access and financial support

Limited market and value chain integration

Access to markets for smallholders is heavily influenced by the availability and quality of transportation, communication and storage infrastructure (Tham, Pretzsch and Darr, 2020). Poor roads, inadequate transport networks and limited processing facilities are common challenges (van Noordwijk, 2019), particularly in remote rural areas, and especially in the Pacific (see Race and Wettenhall, 2024). These areas also often feature difficult terrain, lack of all-weather access and limited availability of essential services. Past or ongoing conflicts, as seen in Lao PDR and Viet Nam, exacerbate these issues (Flanagan *et al*., 2019). In Laos PDR, for example, poor infrastructure has hampered the development of a viable wood industry, making timber transport and marketing difficult and expensive, which in turn limits investment returns (Phimmavong *et al*., 2019).

Smallholders often operate in fragmented markets that lack linkages between producers, intermediaries, processors and customers. In addition, market imperfections often result in lower prices for smallholders (FAO, 2019), while increasingly regulated markets – for example, the European Union Deforestation Regulation (EUDR) – lead to increased transaction costs (Villanueva *et al*., 2023). Insufficient market information hinders alignment with market demand, leading to oversupply or cultivation of low-value species that reduce income (FAO, 2022c). In such contexts, established relations with traders and collectors are crucial to ensure fair prices for farmers, and strengthen farmers' commitment to management for the production of quality wood (Perdana and Roshetko, 2015). Dependence on brokers, however, can be a double-edged sword, reducing the bargaining power of smallholders and resulting in lower prices. Price fluctuations in both domestic and export markets create additional challenges, further discouraging smallholders from investing in agroforestry (Carias *et al*., 2022; van Noordwijk, 2019).

Smallholders also struggle to integrate into value chains due to fragmentation, lack of aggregation and inability to achieve economies of scale (Flanagan, Midgley and Stevens, 2020). The lack of investment in value chain infrastructure – such as processing facilities and market access points – restricts the growth of smallholder wood supply (FAO, 2019) and leaves value chains for agroforestry products, especially bioenergy and non-wood items, underdeveloped (Baral, Leksono and Seol, 2022). Due to narrow profit margins, high quality standards and logistical requirements, only larger smallholder organizations with sufficient capacity and equipment can participate effectively in these value chains and markets (Le *et al*., 2022).

Financial risks and investment barriers

Many smallholders lack the capital for the high upfront investments associated with establishing tree-farming systems, particularly for purchasing quality seedlings, using optimal planting and tending technologies, and maintaining trees until harvest (Race and Wettenhall, 2024). A key barrier is the long delay between investing in trees and realizing revenue from their sale. Quick returns from crops in agroforestry systems do not fully offset this limitation and most agroforestry systems break even only after several years. Many farmers therefore view agroforestry as a risky long-term investment (Springgay and Pajel, 2024).

Transitioning from short- to long-rotation timber production is equally difficult due to the higher risks and lack of premium prices for larger timber (Le *et al*., 2022). In Viet Nam, smallholders are often reluctant to adopt longer-rotation species, despite the potential for better-quality timber, due to financial risks such as storms and pests, compounded by limited access to insurance (Keenan, 2019).

Constrained access to credit, subsidies or financial incentives also restricts smallholders' ability to adopt and scale agroforestry and other smallholder wood production systems (Baral, Leksono and Seol, 2022; FAO, 2019). In emerging economies, high transaction costs and investment risks further constrain wood production and value chain development. The informal nature of many agroforestry systems adds to the risk, deterring formal investors and limiting capital access (FAO, 2022a).

Costs of certification

Certification for wood products has become crucial for accessing international and high-value markets, yet the associated cost and complexity remain significant barriers for smallholders, especially in agroforestry systems (Race and Wettenhall, 2024; Springgay and Pajel, 2024). Certification schemes such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) require extensive documentation, compliance with stringent standards and substantial upfront investments, which smallholders often lack the resources to meet (Flanagan, Midgley and Stevens, 2020; Keenan, 2019).

In Southeast Asia, the costs of certification frequently outweigh its benefits unless subsidized by external initiatives (Flanagan *et al*., 2019; Le *et al*., 2022). Even when certification is achieved, premium prices are not guaranteed, as seen in northern Viet Nam, where certified wood often sells at the same price as non-certified wood. For smallholders, certification is more valuable as a pathway to market access and partnerships with companies committed to sustainable sourcing, than as a direct financial gain (Flanagan, Midgley and Stevens, 2020).

3.1.4 Weak technical capacities, collective organization and partnerships

Limited technical expertise

The effective management of trees depends on the capacities of smallholders. A lack of silvicultural knowledge can result in poor management practices – such as excessive ploughing and burning or insufficient pruning – which lead to poor tree growth, reduced yields, suboptimal timber quality and soil degradation, undermining the long-term viability of wood supply from these systems (FAO, 2022c). The historical separation of the agriculture and forestry sectors has left smallholder tree farmers with limited access to extension services focused on tree management, hampering the adoption of improved practices (Race and Wettenhall, 2024; Springgay and Pajel, 2024). In addition, smallholders frequently lack expertise in processing and marketing wood products, limiting their ability to participate in value chains and to align their practices, including silvicultural management, with market demand and international standards (Flanagan, Midgley and Stevens, 2020; Race and Wettenhall, 2024). In cases where improved technologies are available, smallholders may decide not to use them, as shown with improved acacia seeds in Viet Nam.

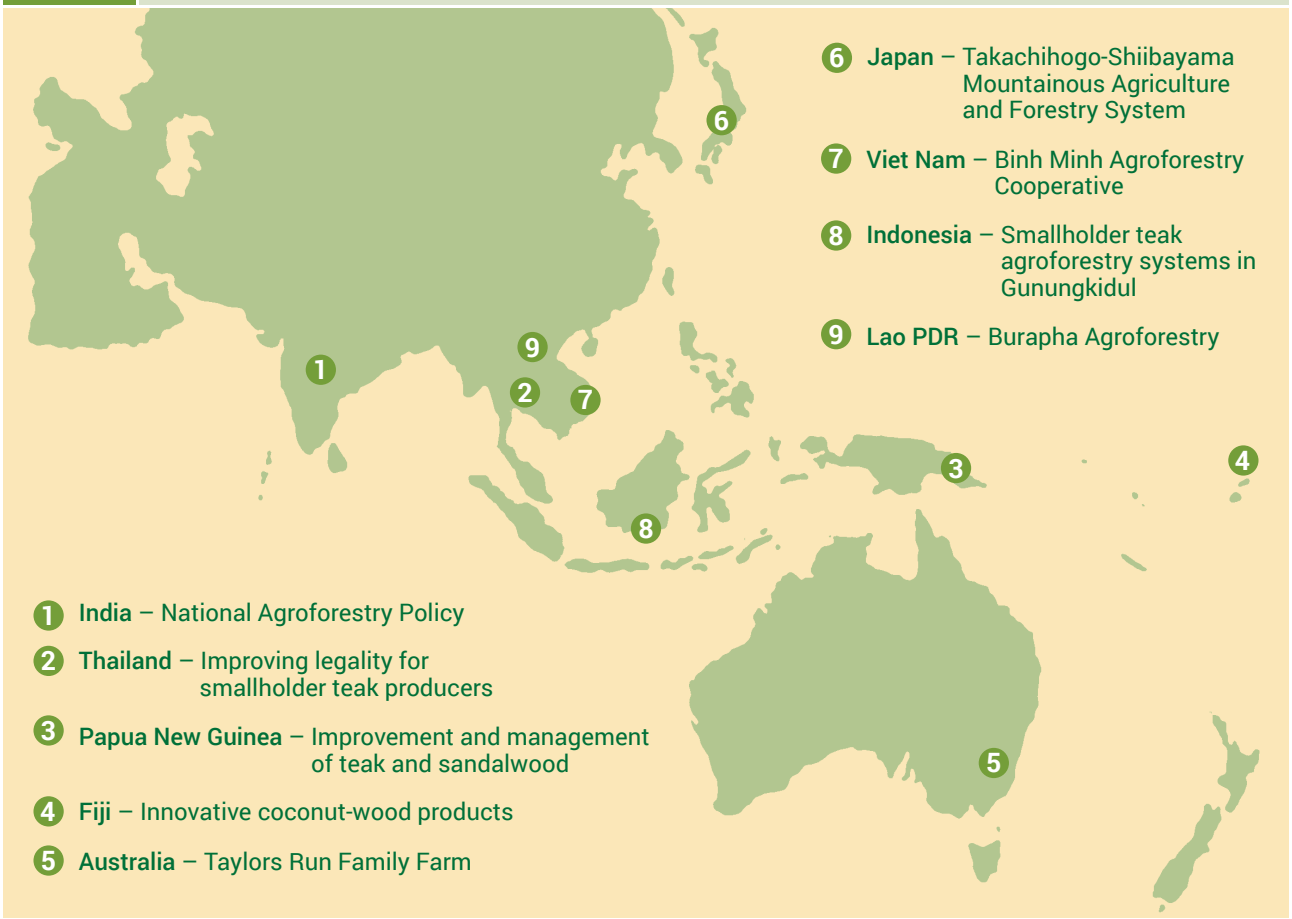
Lack of coordination, collective organization and partnerships

Smallholder tree farmers often work on fragmented plots, limiting their ability to produce wood in quantities sufficient to attract larger buyers. This constraint leads to inefficiencies, reduced bargaining power and difficulties meeting international market standards (Baral, Leksono and Seol, 2022; Le *et al*., 2022), highlighting the need for community-based approaches and cooperative models.

3.2 Effective strategies for enhancing wood production: selected cases from the region

While barriers continue to limit smallholder engagement in wood production, many initiatives across the region are implementing effective strategies to overcome these challenges. This section presents these key strategies and highlights nine illustrative case studies that demonstrate a range of approaches to enhancing wood production in smallholder systems. The selection of these cases was based on several criteria (outlined in Annex 4 on Methodology), including a clear focus on systems owned and managed by smallholders with wood production as a primary objective. The selection also aimed to ensure geographical diversity among the cases and capture a wide range of practices, species and interventions that contribute to strengthening smallholder wood supply.

Figure 5 Illustrative cases studied in the report


6 Japan – Takachihogo-Shiibayama Mountainous Agriculture and Forestry System
7 Viet Nam – Binh Minh Agroforestry Cooperative
8 Indonesia – Smallholder teak agroforestry systems in Gunungkidul
9 Lao PDR – Burapha Agroforestry
1 India – National Agroforestry Policy
2 Thailand – Improving legality for smallholder teak producers
3 Papua New Guinea – Improvement and management of teak and sandalwood
4 Fiji – Innovative coconut-wood products
5 Australia – Taylors Run Family Farm

Source: Authors' elaboration, based on FAO. 2024. Global Administrative Unit Layers (GAUL). Accessed on 1 October 2025. https://data.apps.fao.org/?lang=en. Licence: CC-BY-4.0.

Note: Refer to the disclaimer on page ii for the names and boundaries used in this map.

These case studies present promising examples of success, demonstrating tangible contributions to increased wood production, improved economic viability, enhanced environmental outcomes, and stronger social inclusion and community engagement. While they showcase effective approaches, they are not presented as universally replicable models or one-size-fits-all solutions. Rather, they offer practical insights and lessons that can inform and inspire future efforts for increasing and enhancing smallholder wood supply.

Recognizing the diversity of ecological, socioeconomic and policy contexts across the Asia and the Pacific region, these cases are best viewed as reference points – tools to foster shared understand and to initiate context-specific innovation. Although each case is presented in relation to a specific strategy, it is important to note that most interventions concomitantly address several (if not all) of the main barriers to smallholder tree-farming, reflecting the complex, integrated nature of these systems.

3.2.1 Addressing policy, regulatory and institutional environment barriers

Expanded policy and regulatory support for agroforestry and smallholder tree-farming

Developing cross-sectoral policies and fostering collaboration among the agriculture, forestry and environmental sectors is crucial to reducing the fragmentation that hinders the expansion of viable smallholder tree-farming systems. Efforts underway in India (see Case study 1), DPR Korea and Nepal to adopt integrative agroforestry policies represent promising models for the region as a whole (Park, Baral and Shin, 2022; Springgay and Pajel, 2024). In particular, supportive policies that secure land tenure,

provide incentives, improve access to credit and markets, and ease regulatory barriers for tree harvesting and transport have proven effective (FAO, 2019; Race and Wettenhall, 2024). For instance, policies that simplify the process of harvesting and selling trees from farms can encourage more farmers to adopt agroforestry practices (van Noordwijk, 2019). In Viet Nam, for example, policy reforms relating to tree ownership, land tenure, foreign investment, regulations and trade (e.g. Decision 147 on the promotion of forests for productive purposes) were preconditions essential for the expansion of smallholder woodlots (Midgley, Stevens and Arnold, 2017).

Case study 1 India: A coherent national policy framework for agroforestry

Type of system and wood production, and management objectives

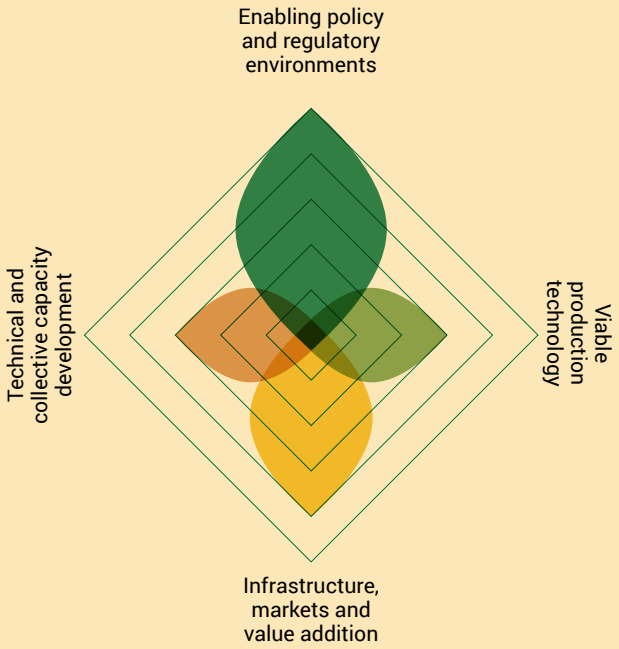
Multiple: The national policy framework does not promote a single agroforestry system but rather focuses on increasing the productivity of barren community lands and other degraded lands. Each state is responsible for identifying the focal tree species of particular relevance to their context. Wood production is one of the main aims of the policy.

Context

India has a long history of agroforestry as part of traditional land management practices and has been actively engaged in agroforestry research for over 40 years. However, prior to 2014, there was no comprehensive institutional or technical support for agroforestry in the country, with the field of work spread across the agriculture, forestry and environmental sectors but lacking a specific mandate. This fragmentation hindered coordinated investment and large-scale adoption. Recognizing these structural barriers, the government, with support from the Centre for International Forestry Research and World Agroforestry (CIFOR-ICRAF), developed the National Agroforestry Policy (NAP), the world's first dedicated national policy to support agroforestry.

Case study 1 *(continued)*

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

The NAP provided a cross-sectoral framework to strengthen agroforestry development at scale, prioritizing wood production to meet growing domestic demand for timber, while reducing reliance on imports and pressure on natural forests. The policy enhanced interministerial coordination, expanded existing agroforestry programmes and integrated agroforestry into the Corporate Social Responsibility (CSR) section of the Companies Act. To support implementation, the NAP established a National Sub-Mission on Agroforestry and strengthened agroforestry research and development institutions.

Outcomes

The NAP's emphasis on wood production has helped reduce reliance on wood imports, meet raw material needs for industries like paper and plywood, and enhanced farmer livelihoods through diversification. Notably, the policy facilitated changes in regulations, such as easing restrictions on harvesting, felling and transportation of trees grown on farms, which directly impacted the availability of wood from agroforestry systems. Within a year of its implementation, in 2014, India recorded a significant rise in the volume of trees outside forests, which now meet 90 percent of the country's domestic timber demand and almost 50 percent of its fuelwood needs. Currently, agroforestry is practised on over 28.42 million ha of land across India.

The policy also catalysed financial investments, including a dedicated agroforestry budget of USD 150 million and investments in technologies to assist uptake, demonstrating how enabling policy environments can trigger cascading effects, leading to widespread support and advancements for agroforestry.

For further information, see the extended version of Case study 1 on India in the Case studies section.

Of equal importance is the translation of policies into effective regulatory frameworks and their appropriate enforcement. In most Southeast Asian countries, smallholder tree growers face complex, inconsistent regulations with high transaction costs (Flanagan *et al.*, 2019; Keenan, 2019). Specifically, restrictive regulations on tree harvesting, transport and marketing, including complex certification processes, discourage smallholders from investing in agroforestry. For example, in Laos PDR, smallholders must navigate complex regulations that often favour larger commercial entities, making it challenging for them to participate in formal timber markets (Carias *et al.*, 2022). Simplifying these regulations, adapting them to smallholder needs, fostering industry self-regulation and consistently enforcing policies would reduce transaction costs and create a more enabling environment for smallholder wood production (Keenan, 2019).

Secure land and resource tenure

Reform of land and resource tenure is essential to promote tree-farming, as seen with the widespread expansion of smallholder investments in eucalypt plantations in southern China following tenure reforms (Arnold *et al.*, 2020). Meanwhile, in Viet Nam, government policy reforms addressing tree ownership and land tenure have positively influenced agroforestry investment (Midgley, Stevens and Arnold, 2017). In Nepal, reforms allowing smallholder farmers to plant trees on government land, and ensuring communal user rights to produce firewood and timber for both household use and sale, were crucial for the country-wide adoption of community forestry. Lastly, clarifying legality and securing tree tenure was crucial for smallholders in northern Thailand to actively engage in sustainable teak production (see Case study 2).

3.2.2 Developing locally adapted, viable production technology

Viable models for smallholder wood production systems

In Viet Nam, smallholders contribute between 50 percent and 60 percent of domestic wood supply (Race and Wettenhall, 2024), primarily from 2.1 million ha of acacia plantations. These plantations are established primarily on degraded or marginal lands unsuitable for conventional agriculture, offering a model for wood production. The viability of these plantations is underscored by their contribution to the national economy, amounting to approximately USD 500 million in annual revenue (Flanagan, Midgley and Stevens, 2022). These smallholder systems rely on fast-growing acacia species, including *Acacia auriculiformis*, *A. mangium* and hybrids, grown in rotation for wood production on plots typically ranging from 3 ha to 5 ha. Plantations are periodically thinned to produce larger logs for the final harvest. This model is economically viable, largely due to its integration with the woodchip export market, which uses thinned

Case study 2 **Thailand:** Improving legality for smallholder teak producers

Type of system and wood production, and management objectives

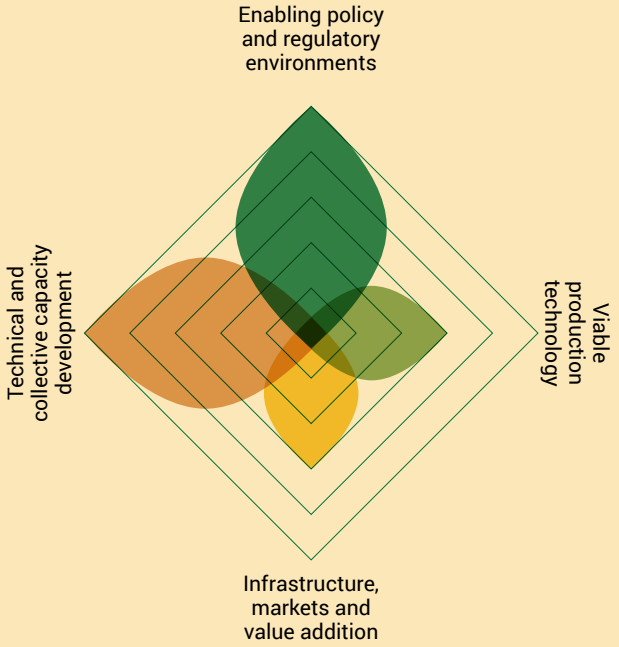
Woodlots: The national policy framework does not promote a single agroforestry system but rather focuses on increasing the productivity of barren community and other degraded lands. Each state is responsible for identifying the focal tree species of particular relevance to their context. Wood production is one of the main aims of the policy.

Context

Thailand aims to increase its forest cover to 40 percent of its land area by 2036. Smallholders are expected to play a key role in this process through tree planting and sustainable timber production on public lands. However, their participation has been hindered by delays in public land allocation and a complex legal framework governing tree planting, timber harvesting, transportation and trade. In Nan Province, smallholders face regulatory barriers including unclear processes for plantation registration, harvesting permits and timber trade. These challenges discourage participation in small-scale forestry and limit smallholders' ability to contribute to national forest restoration efforts and benefit from teak production. To address these challenges, the Regional Community Forestry Centre for Asia and the Pacific (RECOFTC) has been piloting innovative solutions to clarify timber legality and strengthen smallholder resource tenure on public lands.

Case study 2 *(continued)*

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

Smallholders received support to register their plantations under the Forest Plantation Act and secure harvesting permits, providing them with formal recognition of their rights. A comprehensive database (online and paper-based) is used to record plantation boundaries, land tenure and tree-specific data. The initiative also established community-based supply chain controls, ensuring traceability of timber and aligning with legal standards to prevent illegal logging.

Outcomes

Proving the legality of their timber not only addressed immediate and regulatory barriers for smallholders, but also increased their confidence. As a consequence of the reforms, smallholders have organized into a logging group, enhanced their knowledge of plantation management, and negotiated fair and standardized prices for their timber. They are now planning to improve the value of their timber by establishing a local sawmill for lumber processing and partnering with private sector companies to produce wooden products. Secure resource tenure and simplified legal processes have empowered smallholders to engage confidently in timber production.

For further information, see the extended version of Case study 2 on Thailand in the Case studies section.

assortments, and the domestic furniture industry, which uses larger logs (Carias *et al.*, 2022). However, smallholders often face challenges related to equipment and access to quality seedlings. These are frequently overcome with the help of traders who provide essential services and purchase the majority of wood production (Race and Wettenhall, 2024).

While ensuring an appropriate agroforestry systems design is a fundamental aspect of viable smallholder wood production systems, another key component is the selection of tree species that are compatible with agricultural crops. Fast-growing, marketable trees like acacia, teak, eucalypt and sengon have driven smallholder forestry success in Indonesia, Laos PDR, Thailand and Viet Nam. These species provide quick returns, meet market demands and integrate well into smallholder farming systems. Indeed, wood production often hinges on superior planting stock and the proper application of carefully tailored site and stand management technologies (Flanagan *et al.*, 2019; Flanagan, Midgley and Stevens, 2020; IFC Manufacturing Agribusiness and Services, 2018), whereas quick returns on investments with reasonable risk profiles determine economic feasibility. Targeted investments in improving planting stock, site management and silvicultural practices further increase the supply of wood products from agroforestry (Flanagan *et al.*, 2019; Nambiar and Sands, 2013).

Facilitated access to superior and adapted planting stock

The use of high-quality planting stock is central to improving wood quality, increasing yields and minimizing risks of pest, disease and environmental stresses in smallholder systems. Important considerations for the choice of planting stock include fast growth rates (carbon sequestration potential), pest and disease resistance, ease of propagation, adaptability to local environmental conditions, wood quality, nutrient and water efficiency, and suitability for intercropping and multifunctional land management when considered for agroforestry systems. In recognition of these key factors, the Australian Centre for International Agricultural Research (ACIAR) has made considerable contributions to acacia and eucalypt tree breeding and improvement in the region, and is working on teak and sandalwood germplasm to enhance the quality and productivity of the species for the benefit of smallholders (see Case study 3).

The choice of planting stock determines wood quality, which in turn allows for integration into high-value processing chains. This is exemplified by superior eucalypt clones of desirable stem form and wood quality used in southern Chinese smallholder plantations on short rotations and destined for sawn timber and furniture production (Arnold *et al*., 2020).

Species, hybrids and varieties also need to be carefully chosen to match site conditions, as demonstrated by the ill-fated use of cold-tolerant *Eucalyptus dunnii*, which is vulnerable in areas with occasional cold weather. Meanwhile, tropical Acacia species often struggle in cooler regions of China, leading to crown damage or dieback. In southern China, *A. mearnsii*, *A. mangium* and *A. crassicarpa* were grown for tannin production, fibre, charcoal and fuelwood, but their commercial viability declined due to market, climate and stem quality issues. In typhoon-prone regions of China, growers mitigate risks by choosing planting stock less susceptible to wind breakage, such as certain eucalyptus clones (Arnold *et al*., 2020). Superior planting stock of multi-purpose tree species, such as *Pongamia pinnata* and *Calophyllum inophyllum*, helps not only

Case study 3 **Papua New Guinea:** Improving germplasm of teak and sandalwood

Type of system and wood production, and management objectives

Woodlots: Trials tested different methods for cultivating teak *(Tectona grandis)* and Papua New Guinea (PNG) sandalwood *(Santalum macgregorii)* across various sites. Teak is grown for high-quality construction timber, while PNG sandalwood is valued for its high-value oil.

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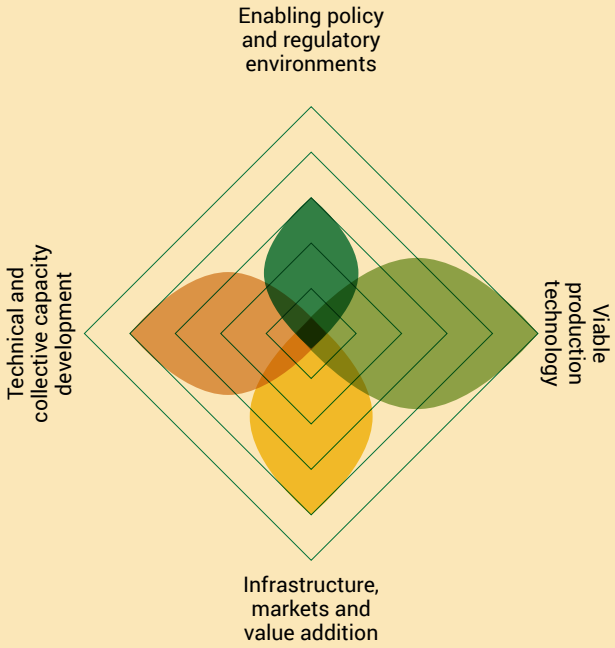
Case study 3 *(continued)*

Context

In many parts of PNG, smallholders have only limited access to high-quality timber resources and commercial opportunities. Smallholder teak production has been constrained by the scarcity of high-quality seeds, while the availability of natural sandalwood has declined due to overharvesting and habitat loss. Despite these challenges, local markets for wild-harvested sandalwood and sawn teak remain strong, providing economic potential for smallholder growers. Teak and sandalwood are prioritized by the Government of PNG due to their strong local and international demand. Teak, known for its robust growth in PNG, produces high-quality timber, while sandalwood, highly valued for its aromatic oil, commands premium prices in international markets. However, maximizing commercial value requires improved genetic selection, particularly to improve heartwood quality and oil yield.

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

To address these challenges, a project by ACIAR and the University of the Sunshine Coast worked to improve germplasm sources for teak and sandalwood, develop viable smallholder silvicultural models and build community capacity for sustainable wood production. For teak, the project created provenance trials to identify superior trees and develop seed production, working to ensure the availability of high-quality germplasm. Cost-effective nursery techniques were introduced, enabling smallholders to establish 38 community nurseries with minimal capital investment. For sandalwood, trials were conducted with six seed sources and multiple host species to improve growth and enhance the commercial value of plantings. High-value germplasm was identified across five populations, with distinct oil and heartwood properties.

Outcomes

The project's farmer extension activities and demonstration plots spurred local demand for sandalwood seeds, creating an emerging market that assigns economic value to mature standing trees and potentially reduces harvesting pressure on the remaining natural seed trees. For teak, the growers' ability to independently establish woodlots without financial support has proven to be a sustainable model, offering significant potential for scaling up as local seed supplies expand.

For further information, see the extended version of Case study 3 on Papua New Guinea in the Case studies section.

to diversify income streams but also to minimize risks, as these species are valued for their resilience, nitrogen-fixing properties and diverse uses, including timber, biofuel and soil restoration (Baral, Leksono and Seol, 2022).

Improved management practices for higher productivity, quality and resilience

Site and stand management are critical not only for enhancing tree health and yield, but also for improving the quality of wood supply. Stand management practices, such as pruning and thinning, enhance wood quality, while intercropping can maintain soil fertility and improve overall site productivity (FAO, 2019). Effective management also prevents resource competition between trees and crops, minimizing mortality losses (van Noordwijk, 2019). The case of smallholder teak production in Gunungkidul, Indonesia, underscores the fact that farmers are sometimes reluctant to thin or prune their stands, which can result in reduced yields and lower quality of timber, and therefore lower incomes (see Case study 8).

As part of good management practices, effective pest management and tree crop protection are essential for ensuring sustainable wood supply. Pests and diseases can significantly reduce tree growth, timber quality and overall yield. Integrated pest management (IPM) strategies, including biological controls,

resistant species and cultural practices, minimize damage while maintaining ecological balance (FAO, 2019). Proper crop protection also reduces competition and resource loss, supporting long-term productivity (Baral, Leksono and Seol, 2022). In places with grazing animals and wildlife, protection of young trees from herbivore damage is essential (Race and Wettenhall, 2024). In Fiji, ACIAR has developed an innovative approach for pest prevention that also advances economic sustainability in the coconut sector (see Case study 4).

Case study 4 Fiji: Pest prevention through innovative utilization of coconut stems

Type of system and wood production, and management objectives

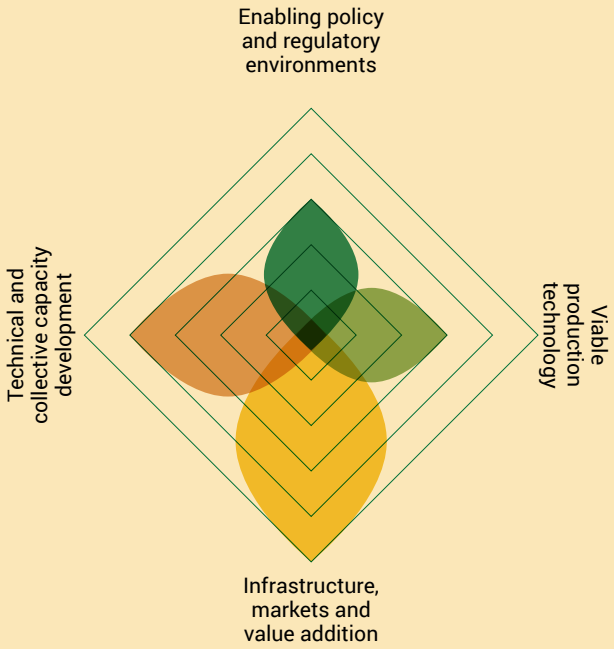
Multiple (woodlots, intercropping and home gardens): This project focuses specifically on coconut palms rather than integrated agroforestry systems. Coconut stands play a crucial role in traditional Pacific agroforestry systems, serving as a critical food source while also providing shade for various food and cash crops.

Context

The Pacific coconut estate covers 65 000 ha in Fiji and 590 000 ha across the region, but faces major challenges due to aging coconut palms that require renewal. The problem is exacerbated by the coconut rhinoceros beetle, a destructive pest that thrives in decaying stumps and debris. This pest infestation reduces coconut productivity, impacting farmer incomes and industry sustainability. To combat this threat, a collaborative research project led by ACIAR and Fiji's Department of Primary Industries is piloting an innovative approach to harvest and transform senile coconut stems into high-value engineered wood products (EWPs), creating economic incentives for farmers to clear and renew coconut stands.

Case study 4 *(continued)*

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

The project utilizes advanced wood-processing technologies, such as spindleless lathe systems, to convert low-value coconut stems into structural and architectural EWPs for both domestic and export markets. By turning stumps into a commercially viable resource, the initiative offsets the cost of replanting by creating a market-driven incentive for coconut stand renewal, while simultaneously mitigating pest outbreaks by reducing breeding grounds. In so doing, it reduces productivity losses caused by pests while safeguarding farmer incomes. The initiative has the potential to revitalize the coconut industry by transforming material once considered waste into a valuable resource.

Outcomes

Preliminary estimates show significant potential: a single operation, processing 7 500 m^3 of veneer annually, could create 26 full-time jobs and produce AUD 6 million worth of veneer products. At a price of AUD 40/m^3, farmers supplying logs could collectively earn around AUD 600 000 annually. The project's long-term benefits include improved profitability for over half a million Pacific households that depend on coconut production for their livelihoods, along with reduced environmental risks from pest infestations.

For further information, see the extended version of Case study 4 on Fiji in the Case studies section.

3.2.3 Strengthening infrastructure, market access and financial mechanisms

Investments in infrastructure to improve market accessibility and reduce costs

Investments in infrastructure are needed, particularly in rural areas, to support the processing, storage and transportation of wood products. This includes investment in roads, storage facilities, processing units and marketplaces (Baral, Leksono and Seol, 2022), to reduce transaction costs and increase profitability (FAO, 2019; van Noordwijk, 2019). The example of Morotsuka village in Japan exemplifies how good infrastructure, particularly roads, can place a community at a unique advantage in supplying wood to far-reaching markets (see Case Study 6).

Value addition and diversification of wood products to meet market demands

Value-addition, such as processing wood into charcoal, furniture or wood panels, significantly enhances the economic viability of wood supply from smallholder systems (FAO, 2019). Examples of small-scale value addition include bamboo handicrafts produced from agroforestry systems in Lao PDR (Park, Baral and Shin, 2022), while large-scale value addition is demonstrated by the veneer industry in China. Investments by smallholders in more advanced processing methods further illustrate the potential for high-value addition, as seen at the Taylors Run Family Farm in Australia, which has integrated on-farm wood processing into its operations (see Case study 5). Similarly, in Viet Nam, government policies encourage smallholders to transition from short-rotation acacia plantations used for woodchips to longer-rotation systems that produce larger, higher-quality logs suitable for furniture manufacturing, thereby unlocking greater value addition potential (Keenan, 2019).

However, it is not possible nor advisable to invest solely in high-quality wood value chains. Finding alternative uses for lesser-quality wood and by-products not only helps to reduce risk by diversifying markets and reducing dependency, it also maximizes income. A prime example of this approach exists in Laos PDR, where acacia wood from smallholder plantations is split between primary markets for veneer and logs and secondary markets for wood chips (IFC Manufacturing Agribusiness and Services, 2018). Similarly, in China, eucalypt logs are processed into veneer (Arnold *et al*., 2020), whereas lower grade wood is used for medium-density fibreboards (MDF) and high-density fibreboards (HDF) (Arnold *et al*., 2013).

Case study 5 **Australia:** Maximizing timber value at the Taylors Run Family Farm

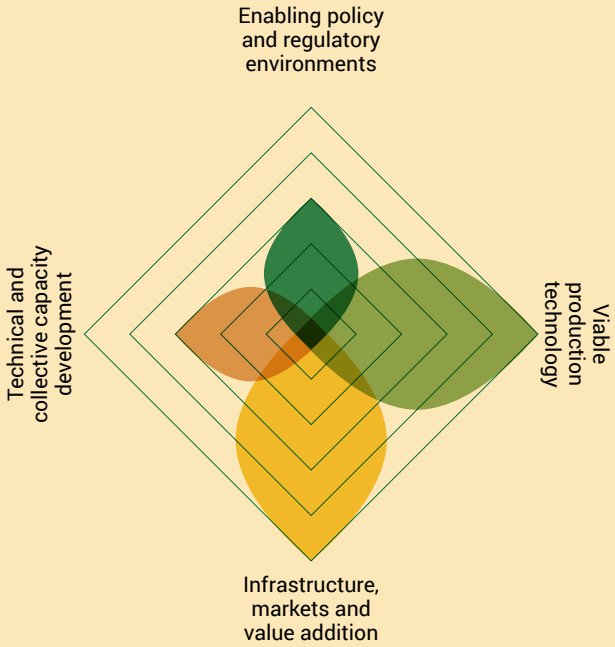
Type of system and wood production, and management objectives

Silvopastoral: The farm keeps 3 500 Merino sheep for wool production and 100 beef cattle, managed alongside radiata pine (*Pinus radiata*) plantations. The pine trees are semi-thinned and extensively pruned to ensure high-quality timber, with an average rotation of age of 35 years.

Context

Taylors Run, a sixth-generation family farm in the New England Tablelands of New South Wales, Australia, demonstrates the transformative potential of value addition for wood production in agroforestry systems. Spanning 750 ha, the family farm may not qualify as a smallholder by global standards, but it is significantly smaller than the average agricultural holding in Australia (4 331 ha), and integrates livestock production with radiata pine plantations as part of a silvopastoral system. Historically degraded, the farm has undergone significant restoration since 1980, increasing tree cover from 5 percent to 23 percent, with a target of 30 percent by 2030. This reforestation effort has not only improved environmental conditions, it has also diversified the farm's economic base.

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

The Taylor family has taken a proactive approach to restoring their degraded landscape, planting over 250 000 trees and creating a distinct silviculture enterprise within their farming system. This includes a comprehensive approach to tree establishment and management, involving direct seeding, tree protection and long-term planning. To maximize returns, they invested in an on-site sawmill to convert low-value pulp logs into higher-value timber, significantly increasing profitability while reducing reliance on external timber markets. The integration of agroforestry required adjustments to pasture management practices, allowing livestock production to continue while accommodating extensive tree plantings.

Outcomes

The farm's investment in value-added processing has yielded significant financial benefits. By converting low-value pulp logs, each worth AUD 0.08, into square-pallet grade timber yielding AUD 23 per log, they achieved an astounding 26 000 percent value increase. Between September 2022 and January 2023, the farm harvested 2 454 m^3 of logs, generating AUD 55 527, with sawlogs and peeler logs accounting for 90 percent of total value despite making up less than half of the harvest volume. In contrast, pulp logs represented nearly half of the harvest volume but only 1 percent of the total value. This value-adding activity has proved pivotal in offsetting the costs of transport and market access, which are important challenges due to the farm's remote location.

Beyond timber production, enhanced tree cover also provides shade and shelter for the farm's sheep and cattle, improving pasture conditions and livestock productivity. The reforested areas have restored biodiversity, while carbon sequestration is estimated at over 600 tonnes annually. By integrating silviculture and livestock production, Taylors Run has diversified its income streams and increased resilience to market fluctuations.

For further information, see the extended version of Case study 5 on Australia in the Case studies section.

Livelihood integration and diversification

Given the potential synergies between trees and annual crops, and the less time-intensive management of trees as compared to agricultural crops, agroforestry enables diversification and potentially greater incomes from the same unit area of land (Race and Wettenhall, 2024). Agroforestry systems that are integrated with local livelihoods and farming practices tend to be more successful. By combining a mix of tree species with food crops or livestock, farmers can diversify their income sources and reduce their reliance on a single product. This diversification helps farmers generate income at different times of the year, but also across different years, reducing reliance on a single source of revenue and increasing

Case study 6 **Japan:** Diversified income streams in Takachihogo-Shiibayama's composite agroforestry system

Type of system and wood production, and management objectives

Multiple (shifting cultivation, woodlots and silvopastoral): The site features a landscape-level composite agroforestry system with the following characteristics:

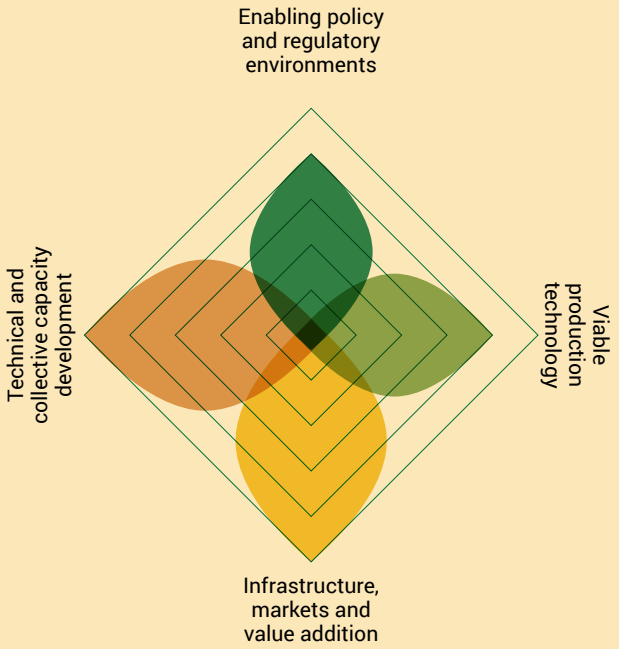
- **Shifting cultivation.** Small plots (0.5–1 ha) are cultivated in cycles of bucket, millet and legumes followed by 20–30 years of fallow for forest regeneration.
- **Mosaic forests.** These consist of jointly managed patchworks of conifers (e.g. Japanese cedar, Hinoki cypress), broadleaf trees (e.g. Sawtooth oak) and evergreen forests. The wood produced is used mainly for shiitake mushroom cultivation and national timber markets.
- **Rice terraces.** These irrigated terraces are situated on steep slopes and fed by canal networks.
- **Cattle rearing.** Carried out on a small-scale, cattle are fed using roughage from local vegetation.

Context

Designated as a Globally Important Agricultural Heritage System (GIAHS), the Takachihogo-Shiibayama Mountainous Agriculture and Forestry System in Miyazaki Prefecture, Japan, is a diversified agroforestry landscape. Approximately 92 percent of the site is forested, with nearly half consisting of planted forests. Despite arable land making up just 3 percent of the area, several traditional agricultural practices, such as terraced rice farming and tea production, thrive on the steep slopes. A key feature of the system is its mosaic-pattern forest, where conifers, broadleaf trees and evergreen species are jointly managed to sustain timber production and shiitake cultivation.

Case study 6 *(continued)*

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

Agroforestry practices are implemented at multiple scales, from household-level farming to broader community-driven forestry management. Timber production is a major activity, with approximately 230 000 m^3 of Japanese cedar and Hinoki cypress harvested annually, much of it sold to national markets. A portion of timber, particularly hardwood species such as Sawtooth oak, is used locally as raw material for shiitake mushroom cultivation, where the mushrooms are grown on natural logs.

Morotsuka village, one of the site's key areas, is a global pioneer in sustainably certified shiitake mushroom cultivation. With FSC certification for both forest management and processing, the village produces over half of Miyazaki Prefecture's dried shiitake output, supplying premium markets and contributing significantly to household incomes. Local timber production also supports initiatives such as the Direct Shipment Housing programme, which connects rural producers with urban consumers by supplying sustainable timber for housing.

Outcomes

The Takachihogo-Shiibayama site supports a highly diversified and resilient rural economy. Wood production activities, together with other agriculture outputs, such as terraced rice, tea, vegetables and high-quality beef, diversify livelihoods and stabilize incomes for the region's households. Investments in infrastructure, including the highest forest road density in Japan, have further facilitated efficient access to high-value markets for both raw and processed products. The site highlights the critical role of diversified markets and value chains in improving rural livelihoods and ensuring the economically viability of these integrated systems.

For further information, see the extended version of Case study 6 on Japan in the Case studies section.

resilience against market or climate shocks (Baral, Leksono and Seol, 2022; van Noordwijk, 2019). By combining wood production with agricultural outputs, agroforestry systems can provide early positive returns and increase financial resilience, making them more attractive for investment (FAO, 2022a).

Intercropping trees with food crops diversifies income, reduces risks and supports food security, enhancing agroforestry's economic viability (Carias *et al.*, 2022). In Japan, the Takachihogo-Shiibayama system presents an example of an agroforestry system with diversified income streams at the landscape level (see Case study 6). Additional examples of systems that provide multiple revenue streams, addressing both household and market needs, include models that combine fuelwood or bioenergy species with high-value timber (Baral, Leksono and Seol, 2022).

Group certification – a means to access reliable and premium markets for wood products

Group certification is a practical and cost-effective strategy aimed at overcoming the barriers to smallholders represented by certification. By forming cooperatives, smallholders can share certification costs, reduce administrative burdens and collectively meet the stringent requirements of schemes like FSC and PEFC (Flanagan, Midgley and Stevens, 2020). This approach also enhances smallholders' bargaining power, enabling them to enter certified markets and more sophisticated value chains (Flanagan *et al.*, 2019).

Collaborative partnerships among smallholders, non-governmental organizations (NGOs) and private sector actors may further support certification efforts. NGOs can offer technical guidance and capacity-building to help smallholders navigate the complexities of certification, while private companies can offer market

access opportunities for certified products (Flanagan *et al*., 2019). Inspiring examples include cooperatives in Viet Nam that have leveraged FSC chain-of-custody certification to sell certified acacia sawn timber to global companies like IKEA (see Case study 7). This has enabled smallholders to secure more reliable income streams and access high-value international markets. However, the issue of sustainability after the technical assistance to communities ceases needs further consideration.

Financial compensation for ecosystem services generated from tree-farming

The integration of trees into the landscape, including through agroforestry, not only increases the availability of wood and bioenergy resources; it also provides critical environmental services, such as improved soil fertility, carbon storage and water regulation, making tree-farming a sustainable choice for smallholders and policymakers (Baral, Leksono and Seol, 2022). By integrating food crops with trees, these models enhance food security and contribute to land restoration. For example, in Nepal, within the scope of a project funded by the Green Climate Fund (GCF), the government with the support of FAO is implementing agroforestry to increase the climate resilience of smallholders, particularly by improving soil fertility and stabilizing slopes (see Box 3).

In Laos PDR, smallholder tree production systems can support forest transition by offsetting natural forest loss with planted forests over time (Phimmavong *et al*., 2019). Smallholders are increasingly aware of the environmental benefits of their plantations, which include enhanced soil fertility, biodiversity conservation and climate regulation. Recognizing these ecosystem services through market-based incentives or payments for ecosystem services (PES) can provide additional income streams for smallholders (FAO, 2022a; Keenan, 2019) through either stacking or bundling relevant ecosystem services (Cooley and Olander, 2011).

Case study 7 **Viet Nam:** Private sector partnerships empowering the Binh Minh Agroforestry Cooperative

Type of system and wood production, and management objectives

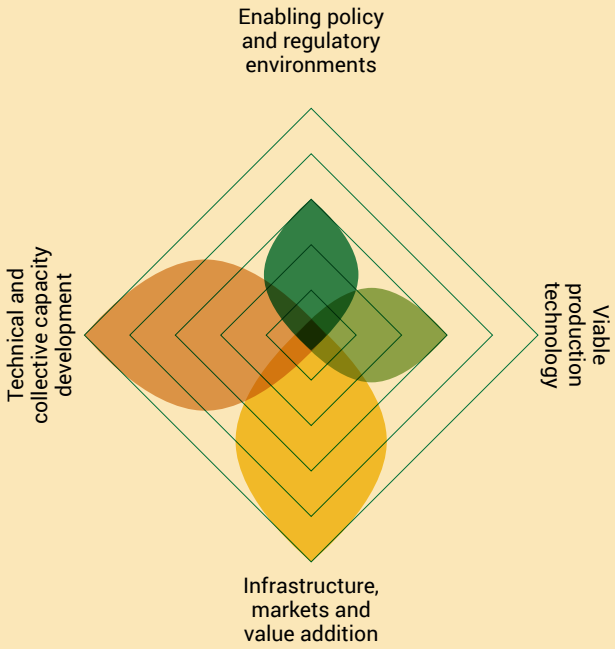
Woodlots, intercropping: Cooperative members grow acacia primarily in woodlots, producing FSC-certified timber. Many also diversify by integrating crops and fruit trees and utilizing the understory for honeybee farming and poultry, both for household use and sale.

Context

The Binh Minh Agroforestry Cooperative is located in the mountainous Yen Bai Province of northern Viet Nam, where forestry and agriculture are key economic sectors. Initially a small group of acacia growers, the cooperative has grown into a formalized enterprise managing 60 ha of FSC-certified plantation forest.

Case study 7 *(continued)*

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

With support from the Forest and Farm Facility (FFF) and the Viet Nam Farmer's Union (VFNU), the cooperative received technical training, secured FSC certification and established private sector connections. A key partnership with Hoa Phat, one of the largest timber processors in northern Viet Nam, provided the cooperative with a stable market for their FSC-certified acacia timber, ensuring consistent demand and fair pricing. The establishment of the cooperative's sawmill, which processes 1 000 m^3 of timber monthly, represented a significant step forwards and was facilitated by private sector collaboration with Hoa Phat. Hoa Phat also provided technical guidance on timber specifications and quality requirements, enabling the cooperative to meet international standards.

Outcomes

FSC certification has allowed the farmers to earn 10–15 percent more for their timber. Between 2018 and 2022, the cooperative generated revenues of USD 265 000, averaging USD 53 000 per year, and created 15 full-time jobs for local workers. Partnerships with Hoa Phat and other private companies strengthened the cooperative's bargaining power, reduced reliance on intermediaries and provided access to larger, more lucrative markets.

Binh Minh's success reflects several enabling factors: strong leadership, member solidarity, capital availability and stable wood product markets, supported by comprehensive government support. It underscores the importance of multistakeholder collaboration, where government, private companies and donor initiatives provide market incentives, technical expertise and policy support to sustain and grow smallholder wood production enterprises.

For further information, see the extended version of Case study 7 on Viet Nam in the Case studies section.

Upgraded financial services and instruments

Financial services and instruments tailored to the circumstances of smallholder woodlots are seen as important upgrading strategies to overcome the initial investment burden associated with establishing smallholder wood production systems. Tailored financial mechanisms, such as subsidies or low-interest loans, could help smallholders cover initial establishment costs (Flanagan, Midgley and Stevens, 2020). However, these need to be designed carefully with clear long-term markets to avoid indebting poor farmers (Barney, 2008).

Carbon finance can provide much-needed funds for farmers to overcome the investment burden of integrating trees into agricultural systems. However, national agenda setting is required to enable wide-spread adoption (Dhyani *et al*., 2021). Overall, carbon finance, at present, is marginal in terms of financial volume (FAO, 2022a) and has not yet been applied on a wide scale in most countries of the region. In smallholder systems it is also constrained by low carbon credit prices, lack of enabling national policies, limited capacities for project development and lack of financing mechanisms for project development. At the same time, promising cases, such as corporate zero-deforestation pledges using carbon finance, have incentivized communities and smallholders towards restoration in Borneo (Mikolajczyk *et al*., 2021), demonstrating the viability of well-designed carbon forestry projects for smallholders.

Box 3 Restoring ecosystem services through agroforestry in Nepal

The Churia region, located in Nepal's southernmost Himalayan foothills, plays a vital role in sustaining downstream communities in the Terai plains and northern India. Its forests and ecosystems provide critical services such as groundwater regulation, flood control and soil stabilization. However, a combination of fragile geological features, decades of deforestation and unsustainable resource management, and reliance on climate-sensitive livelihoods has left communities highly vulnerable to climate-induced hazards such as erosion, landslides and seasonal water stress.

The project "Building a Resilient Churia Region in Nepal" (2020–2027), funded by the Green Climate Fund (GCF) and implemented by the Government of Nepal with FAO's support, seeks to address these challenges by promoting agroforestry as a climate-resilient and sustainable land management practice. Agroforestry is designed to improve soil fertility and productivity while reducing pressure on forests and stabilizing slopes. By providing households with alternative sources of wood, fuel and fodder, agroforestry minimizes the need for wood extraction from forests, contributing to minimizing forest degradation.

A key component of this project is the establishment of on-farm agroforestry nurseries featuring multipurpose species for fuelwood, fodder and fruit. Early project results indicate that communities are particularly interested in fruit-bearing trees due to their potential to generate immediate benefits, such as supplemental income and improved food security. The project is also implementing Natural Resource Management (NRM) farmer field schools where participants are trained in a package of climate-resilient practices, including agroforestry and livestock management.

Collaborative investment models present an attractive financial instrument for the integration of trees into agricultural landscapes. In such models, private investors assume most of the risk, making agroforestry a more attractive option for smallholders (Phimmavong *et al.*, 2019). Investor needs must be balanced with community benefits, as demonstrated in Lao PDR, where investors establish trees on smallholder land, while community members grow agricultural crops like rice or cassava alongside eucalyptus in the early years.

3.2.4 Building technical capacities, strengthening collective organization and fostering partnerships

Upgraded technical advisory services

Investment in the capacity-building of smallholders and government officials is critical. The capacities of institutions in charge of agroforestry need to be strengthened (Catacutan *et al.*, 2018) alongside the development of extension services, participatory trials, educational curricula and agroforestry training (Catacutan *et al.*, 2018; Race and Wettenhall, 2024). Extension services need to be in place to provide technical advice on appropriate technologies, facilitate access to quality inputs including planting stock, and impart tree management training to smallholders, to enhance their wood production (van Noordwijk, 2019).

Investment in training programmes can empower local farmers and encourage widespread adoption of trees on farms (Baral, Leksono and Seol, 2022). Training programmes are especially valuable when they focus on species selection, tree-crop interactions, silviculture practices (including planting techniques, spacing, and pre-commercial and commercial thinning), harvesting, post-harvest processing and market dynamics. These aspects are of particularly importance to improve the quantity, quality, reliability and profitability of wood production (Catacutan *et al*., 2018; Keenan, 2019; Le *et al*., 2022). Engaging with governments, NGOs, community organizations and research institutions, as essential stakeholders, is vital to ensure the effective capacity building of smallholders (Springgay and Pajel, 2024). The case of teak agroforestry in Gunungkidul, Indonesia (see Case study 8), highlights the potential for targeted capacity building to improve smallholder incomes.

Case study 8 **Indonesia:** Smallholder teak agroforestry systems in Gunungkidul

Type of system and wood production, and management objectives

Multiple (home gardens, woodlots and boundary planting): Smallholder farmers in Gunungkidul integrate teak into four agroforestry systems:

- **Kitren** are teak-dominated woodlots, located typically 1–1.5 km from homes.
- **Tegalan** refers to upland intercropping with teak and annual crops (cassava, peanuts and upland rice), also situated 1–1.5 km from homes.
- **Pekarangan** are home gardens located adjacent to farmers' homes, dominated by tree species, including teak, with crops in the understory.
- **Border plantings** consist of teak planted along borders of irrigated fields and other cropping systems.

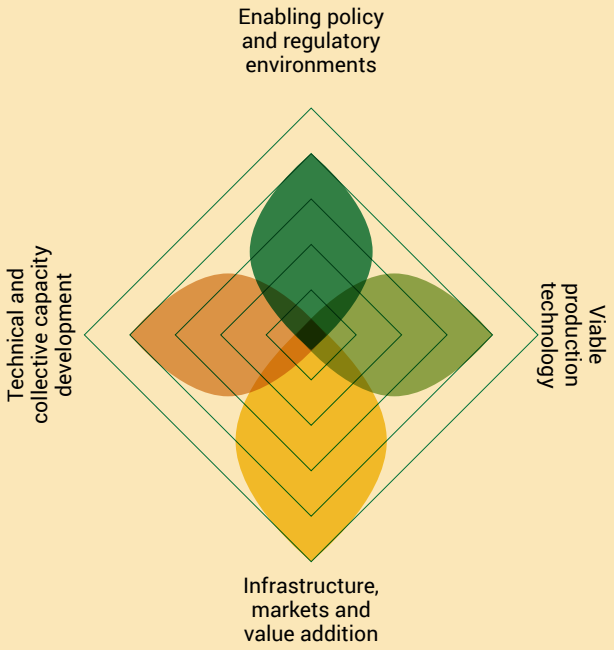
Context

Gunungkidul, in Yogyakarta, Central Java, is a key centre for smallholder teak production, where nearly every farming household integrates teak cultivation into their livelihood strategies. The region plays a vital role in Indonesia's teak industry, with smallholder contributions underpinning local economies and timber markets.

In the 1950s, Gunungkidul faced severe environmental degradation due to agricultural expansion on marginal lands to support a growing population. Over the past seven decades, smallholder farmers have adopted agroforestry practices, spanning woodlots, upland intercropping, home gardens and border plantings, and have transformed degraded landscapes into productive and sustainable ecosystems.

Case study 8 *(continued)*

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

Since 2007, CIFOR-ICRAF, research agencies, local governments and private sector partners have collaborated on initiatives in Gunungkidul to improve smallholder teak systems, enhancing timber and NWFPs, marketing and sustainable livelihoods. The expansion of smallholder teak agroforestry has been driven by spontaneous tree planting by farmers, the government's penghijauan (reforestation programme) and collaborative efforts led by the above stakeholders.

Families own an average of 1 ha of land, typically divided into multiple parcels, with 30–50 percent dedicated to teak. For many smallholder families, teak trees serve as a "living savings account", selectively harvested to cover major expenses, such as weddings, education or medical needs – a practice known locally as *tebang butuh* ("felling for needs"). While this strategy provides crucial financial stability, it leads to inconsistent wood supply and suboptimal timber quality. Reluctance to thin stands, stemming from a belief that this practice reduces future income, results in dense plantings that limit tree growth and quality. Farmers often target the best-quality trees for harvesting, further reducing the long-term potential of their plantations.

Outcomes

Despite these challenges, smallholder agroforestry systems supply approximately 80 percent of the teak used by small and medium-scale producers in Central Java, making them indispensable to Indonesia's teak industry. To address issues of quality and consistency, interventions such as capacity building on thinning and pruning, collective marketing groups and transparent pricing mechanisms are crucial. These measures can incentivize better management practices while maintaining teak's role as a financial safety net.

For further information, see the extended version of Case study 8 on Indonesia in the Case studies section.

Increased private sector engagement and linkages with businesses

Engaging with the private sector is crucial to facilitate investments in smallholder tree production systems and to improve their integration into value chains and access to markets. When governments, investors and communities collaborate, they can reduce risks, align incentives and create a more enabling environment for smallholders to participate in wood value chains (Keenan, 2019). The best performing systems have reliable connections with a broad range of value chain actors, including processors and traders, and other service providers, which allow smallholders to stabilize demand for their wood products (Race and Wettenhall, 2024). In cases where plantation development is driven by private investors, contract farming arrangements (outgrowing schemes) have proved to be most beneficial for smallholders (Van Der Meer Simo, 2020). Connections between smallholders and companies can result in the provision of inputs and seedlings, as well as technical assistance in addition to direct payment. Indeed, examples from Indonesia and Viet Nam demonstrate how smallholders linked to processing companies gain better prices for their wood and access to stable markets. In addition, long-term supply contracts with processors not only provide farmers with income stability, they also encourage them to invest in improving wood quality (Carias *et al*., 2022).

However, partnerships between the private sector and smallholders – two stakeholder categories with very different values, beliefs, knowledge systems and motivations – require transparency and mutual understanding. Intermediaries can play a vital role in bridging this gap and aggregating smallholders' outputs, managing logistics and navigating market dynamics, often providing advance payments and essential market knowledge (Flanagan *et al*., 2019). The processing, marketing, sales and transport services provided by wood traders to smallholder woodlot owners in Indonesia and Lao PDR demonstrate how these

types of partnerships can enhance the efficiency of supply chains, profitability and competitiveness in both domestic and international markets (Flanagan *et al.*, 2019). Organized market linkages, cooperatives and direct connections with buyers improve pricing and demand stability for smallholders' timber and non-timber products (van Noordwijk, 2019).

Collaborative investment models, which combine timber production with local food production, exemplify a balanced approach to agroforestry. In these kinds of models, smallholders grow crops like rice or cassava alongside eucalypts, with private investors assuming much of the financial risk for the integrated tree crop. This structure meets both investor and community needs by providing short-term income through food crops while developing long-term timber resources (Phimmavong *et al.*, 2019). This is exemplified by the Burapha Agroforestry model from Laos PDR (see Case study 9).

The private sector can be instrumental in expanding smallholder wood production, as seen in southern China. Here, small-scale veneer mills and smallholder eucalypt plantations mutually fuel expansion, driven by the rapidly increasing demand for plywood in China and the rising prices paid by veneer mills for small-size

Case study 9 **Lao People's Democratic Republic (PDR): The Burapha Agroforestry model**

Type of system and wood production, and management objectives

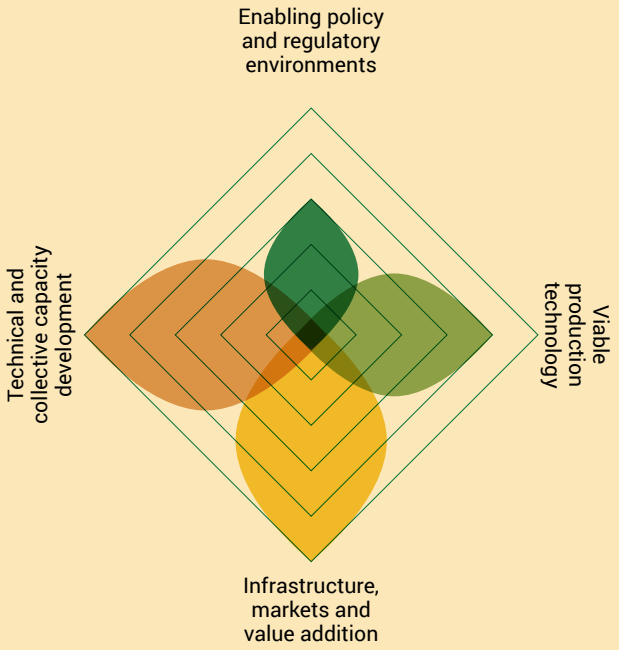
Woodlots, alley cropping, sequential: Timber plantations are composed primarily of eucalyptus, with some areas also planted with teak and acacia. In the early years, they are intercropped with agricultural crop, with the alleys later used for grazing.

Context

Lao PDR's wood-processing industry relies heavily on timber plantations, which supply approximately 90 percent of the country's roundwood, with eucalyptus and teak as key commercial species. The Burapha Agroforestry Company is a plantation and timber wood-processing company that manages plantations through an agroforestry model. Today, it manages 9 622 ha of land, primarily in Vientiane Prefecture and the provinces of Vientiane and Xayabouly. The region is characterized by hilly and degraded forestland that has been historically shaped by shifting cultivation.

Case study 9 *(continued)*

Weighing different strategies


Enabling policy and regulatory environments
Technical and collective capacity development
Viable production technology
Infrastructure, markets and value addition

Approach and activities

The Burapha model initially involved leasing degraded forestlands from communities and individual landowners, providing lease payments, seasonal employment, land preparation for intercropping between the trees and support for village infrastructure improvements. The company utilizes a sequential intercropping model integrating timber production, agricultural crops and livestock grazing. During the first two years of each seven-year plantation cycle, rows of eucalyptus, teak and acacia trees are intercropped with upland rice and other crops. From year three onwards, as the canopy closes, grazing is introduced under the trees. This seven-year cycle is then repeated until the end of the lease agreement.

In 2020, Burapha was granted a government concession for 2 000 ha within the production forest area (PFA). In 2022, this was expanded to include the right to survey and identify suitable land up to 60 000 ha of PFA, in agreement with farmers and the government. Since then, the company has focused on establishing new plantations exclusively within the PFA. To date, over 2 200 ha have been planted.

Outcomes

Burapha's agroforestry model supports the restoration of degraded land, focusing on areas previously affected by swidden agriculture. The plantations are located primarily in foothill areas, deliberately avoiding sensitive habitats, floodplains and native forests. The design promotes biodiversity corridors, protects waterways and enhances soil health through intercropping practices. Furthermore, 1 381 ha within or adjacent to the plantations are set aside for conservation. Burapha's agroforestry system demonstrates how careful planning can combine socioeconomic benefits, sustainable land use and ecological restoration.

For further information, see the extended version of Case study 9 on Lao PDR in the Case studies section.

eucalypt logs (Arnold *et al*., 2020). In Viet Nam, partnerships between smallholders and the private sector are responsible for a substantial part of acacia wood supply to plywood, particleboard and other wood-processing industries (Flanagan, Midgley and Stevens, 2022). In southern China, lower-value eucalypt logs not suitable for veneer production are utilized in the pulp and paper industry. Some companies like APP and Stora Enso have established large eucalypt plantations to support their pulp mills (Arnold *et al*., 2020).

Community-based approaches and cooperative models

Aggregating smallholders into community-based initiatives, such as corporations, cooperatives and nonprofits, improves market access, can help achieve economies of scale, increases bargaining power, reduces transaction costs, and improves access to resources, information, knowledge, skills development and capital, ultimately strengthening wood-based value chains (Race and Wittenhall, 2024; van Noordwijk, 2019). For instance, cooperatives in Indonesia facilitate collective marketing, quality control and value addition, strengthening smallholder market positions.

Effective agroforestry systems often prioritize social equity, particularly involving marginalized groups like women, Indigenous Peoples and youth, leading to higher adoption rates and sustainable practices. However, top-down established cooperatives are generally non-functional, while successful cooperatives depend on strong leadership, mutual trust and organized governance (Le *et al*., 2022).

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4 The way forward

4.1 Scaling-up agroforestry for wood production: the role of public policymakers

While a wealth of strategies to enhance the efficiency, competitiveness, sustainability and inclusiveness of wood production from smallholder tree-farming systems have been explored in the Asia and the Pacific region in recent decades, new and complementary pathways need to be investigated to ensure the long-term viability of smallholder tree-farming in a fast-changing world. This chapter outlines seven pathways that address the alignment of enabling environments, the development of innovative products and technologies, the utilization of new raw materials and more. Policymakers can help advance wood production from smallholder systems by creating the conditions necessary to implement these pathways.

4.1.1 Intensifying efforts to strengthen enabling environments for smallholder tree-farming

Policy development and institutional responsibility

Successful cases exist where agroforestry and smallholder wood production have been elevated onto national agendas through the formulation and implementation of dedicated agroforestry policies at the appropriate levels, for example in India or Nepal. Research efforts on agroforestry policy development and strategy implementation provide valuable insights for countries currently working to advance such frameworks (Baral, Shin and Murdiyarso, 2023). The tangible benefits generated in these contexts – such as increased farmer participation and private sector engagement – may provide a foundation for adoption in other countries across the region. Furthermore, effective policy processes tend to involve key government stakeholders along with value chain actors ranging from smallholder farmers to wood-processing industries, financiers and investors.

The coherent implementation of enabling policies is as important as their development. Policies streamlining the involvement of intermediaries, as well as the implementation of regulations on minimum and guaranteed prices, and follow-up on improved access to long-term finance, are particularly crucial. Examples include rubber plantations with supportive schemes in Thailand, a platform for connecting smallholders with the wood industry in Indonesia, and an e-commerce platform allowing producers to avoid intermediary costs in India. The coherent implementation of enabling policies requires clarity of institutional mandates for smallholder wood production systems, including agroforestry. Ideally, a dedicated institutional home is identified with capacities and mandates that capture the specifies of smallholder wood production systems at the interface of forestry and agriculture.

Examples of actions:

- Initiate inclusive processes for agroforestry policy design.
- Address policy barriers and incoherencies in regulations that may restrict smallholder wood production, market access or private sector engagement.
- Establish clear institutional responsibilities for smallholder tree-farming oversight (Catacutan *et al*., 2018; Lin *et al*., 2021).

Land use planning

The landscape approach and integrated land use planning processes, institutionalized at various hierarchical levels, can play a pivotal role in guiding the strategic spatial placement of agroforestry and smallholder tree-farming within landscapes. These processes can contribute to the conflict-free development of agroforestry at the intersection of agriculture and forestry by reconciling competing land use interests (Mouratiadou *et al*., 2023). Developing short, medium and long-term multi stakeholder plans will guide coordinated implementation and adaptive management.

Examples of actions:

- Codify legally binding cross-sectoral land use planning systems consisting of multi level hierarchic planning and mandatory stakeholder consultation processes in countries where these systems have not yet been established.
- Mainstream the implementation of integrated land use planning processes at national and sub national levels.
- Establish or strengthen subnational multistakeholder and cross-sectoral coordination platforms to support agroforestry planning and implementation.

Land and resource tenure security

The creation of clear and secure tenure conditions over land and trees is a precondition for investments in smallholder agroforestry and tree-farming. More lenient regulations for harvesting trees farmed in smallholder systems can provide incentives for the uptake of agroforestry or smallholder woodlots. The consolidation of land tenure and land use rights in Viet Nam represents a positive example of an approach enabling smallholder tree-farming systems.

Examples of actions:

- Pursue efforts to formalize smallholder land titles and ensure the recognition of rights and access to benefits from trees. Examples include the Forest Land Allocation programme in Viet Nam (Catacutan *et al*., 2017).
- Advance the formal recognition of collective and/or individual traditional land and resource rights. An example is the recognition of communal forest rights in Indonesia, referred to as *hutan kemasyrakatan* (Jong *et al*., 2018)
- Explicitly integrate wood production into national social forestry/community forestry programmes, including for commercial purposes. An example of this approach is provided by Nepal's community forestry programme, which allows community forest user groups to commercially harvest and sell timber including of high-value species.

4.1.2 Advancing the professionalization and empowerment of tree farmers

Development of networks and cooperative models

Evidence from the region shows that the aggregation of producers can yield significant benefits for smallholder farmers. Community-based initiatives such as farmer cooperatives and producers' networks have demonstrated value in fostering knowledge sharing and collective market participation (FAO, 2019). Strengthening social networks through farmer-to-farmer mentoring has been highlighted as an effective strategy to scale-up the adoption of smallholder tree production systems by helping smallholders to adopt optimal wood production systems, set realistic market expectations and achieve fair prices for their produce (Race and Wettenhall, 2024). Similarly, the establishment and strengthening of cooperatives can enhance collective bargaining power, facilitate bulk purchasing of inputs, improve access to processing facilities and support the collective marketing of wood products, which can in turn increase the profitability and sustainability of smallholder agroforestry systems (van Noordwijk, 2019).

Examples of actions:

- Create a supportive policy and legal environment that encourages the aggregation of smallholders into producers' organizations, thereby strengthening their position in value chains and improving collective access to markets
- Further support peer-to-peer learning and knowledge exchange by encouraging mentoring, producer networks, knowledge fairs and other means of sharing good practices to enhance knowledge and skills.
- Support community-based forest enterprise development. By taking cooperative structures and value chain development to the next level, viable community-based forest enterprises have the potential to invigorate rural economies in what are frequently impoverished regions. In one example from Sulawesi, Indonesia, a community forestry enterprise operating agroforests, obtained FSC certification through the *Hutan Kemasyarakatan* programme, which facilitated access to high-value timber markets for species like albizia and sengon (Harada and Wiyono, 2014).
- Support collective marketing strategies for smallholder wood and agroforestry products to ensure fair pricing, increase profitability and enhance the long-term sustainability of agreements.

Access to markets and information

Improving smallholders' market access through investments in cooperative models, enhanced market linkages and value chain development has proven an effective means of improving their ability to participate in wood and bioenergy markets (Baral, Leksono and Seol, 2022). Additionally, digital market platforms, market information systems and local marketplaces can help smallholders connect directly with buyers, reducing reliance on intermediaries and improving income stability (FAO, 2019). However, there is growing recognition of the need for technical and trade promotion support to strengthen the development of agroforestry value chains and expand market linkages (Catacutan *et al*., 2018). The exchange of lessons and best practices through knowledge hubs could address related barriers and foster the upscaling of smallholder wood production systems across the region (Lin *et al*., 2021).

In addition to strengthening existing market channels, there is significant potential to establish new markets for agroforestry products and lesser-used species beyond fast-growing tree species. Diversifying the range of marketable species and products, such as high-value hardwoods, the timber of native tree species and NWFPs (e.g. mushrooms, resins and medicinal plants), can increase income opportunities, provided markets exist or can be developed at realistic cost. However, realizing this potential requires targeted technical support for farmers to cultivate the concerned species, and harvest and process these products effectively. Investments in product innovation, market research and consumer education are also key to stimulating demand and ensuring competitiveness in both domestic and export markets.

Examples of actions:

- Improve access to real-time market information for smallholders. An example is provided by Viet Nam, where farmers with instant access to market information timed their timber harvests, increasing their income by 40 percent (Nambiar, 2021).
- Develop products and markets for less preferred species and by-products. An example from Central Viet Nam demonstrates product development from by-products of acacia, including charcoal briquettes, furniture timber from larger logs and engineered wood products from small assortments (Tham, Darr and Pretzsch, 2020).

Financial incentives and credit access

Financial support mechanisms, including subsidies, grants, credit facilities, lower interest rates, tax holidays, insurance premiums and incentives for the provision of ecosystem services, have been recognized as effective tools to encourage smallholders to integrate trees into their farms (Catacutan *et al*., 2018). Emerging approaches, such as regional investment hubs, provide platforms for collaboration among smallholders, investors, project developers and regulatory authorities, creating opportunities to channel sustainable investments into smallholder wood production systems. Formalized coordination between critical actors, including local governments, the private sector and farmers, can ensure more effective and sustainable investments (Race and Wettenhall, 2024), and promote the development of financial instruments and incentive programmes. For example, initiatives that lower the upfront costs of tree planting and maintenance while rewarding sustainable practices, such as PES as well as carbon and biodiversity credits, can make agroforestry more accessible and attractive to smallholders (Baral, Leksono and Seol, 2022; FAO, 2019; van Noordwijk, 2019).

Examples of actions:

- Scale up existing smallholder financing mechanisms to incentivize poorer smallholders' investments (World Bank, in press)
- Permit the use of trees by smallholders as collateral for loans. A prime example for this exists in Thailand, where such regulatory easement led to substantial expansion of smallholder wood production (Starfinger, 2021).

4.1.3 Producing data on smallholder tree-farming systems and their outputs

A common challenge at the national level concerns the lack of a standardized definition of agroforestry and other types of wood production systems. Limited reporting on agroforestry as a distinct land management system is also an issue. Addressing these gaps through more consistent data collection and classification could allow for more accurate policymaking (Springgay and Pajel, 2024).

Investments in spatially explicit tools can further support the effective planning and management of agroforestry at various scales. In addition, integrating standardized agroforestry data into global, regional and national databases and reporting systems can strengthen the evidence base for decision-making (Catacutan *et al*., 2018). The development of robust monitoring and evaluation (M&E) systems to assess the long-term impacts of agroforestry practices on wood production, livelihoods and environmental health, will be essential in this regard. Such M&E research would provide data to guide policy decisions, and help to refine agroforestry models based on identified best practices (FAO, 2019).

As agroforestry research has traditionally focused on the biophysical aspects of agroforestry, while neglecting income-generating capacities, there is a need for intensified efforts to understand the functioning of market-based strategies, the assessment of costs and benefits, and the mobilization of financial resources for agroforestry projects (Springgay and Pajel, 2024). The compilation and sharing of wood supply chain data would be valuable here to enable the targeted removal of bottlenecks in smallholder wood supply.

Examples of actions:

- Adopt common definitions of agroforestry and other types of smallholder wood production systems, nationally and internationally, and introduce standardized data collection on agroforestry as a distinct land management system
- Integrate standardized agroforestry data into global, regional and national databases and reporting systems, and include agroforestry in national accounting systems (Lin *et al*., 2021)
- Support research efforts geared at developing robust M&E systems, to assess the long-term impacts of agroforestry practices on wood production, livelihoods and environmental health.
- Improve understanding of the functioning of market-based strategies, the assessment of costs and benefits, and the mobilization of financial resources for agroforestry projects.
- Develop tools to optimize the site-specific design of multi-species wood production systems, including through the use of Artificial Intelligence.

4.1.4 Enhancing the selection and production of genetically adapted high-quality germplasm

Improvement of planting material

The growing demand for exotic and tropical wood globally underscores the need for ongoing research into improved planting material for priority species. Such research is particularly important for multi-purpose tree species and their genetic improvement for smallholder wood production systems. A key priority is improving climate resilience to maintain wood supply under adverse climatic conditions. This includes identifying species that are drought-tolerant, pest-resistant and adaptable to different soil types (van Noordwijk, 2019). Understanding these dynamics can guide the selection of species and management practices for climate-proofing tree-farming systems (FAO, 2019).

Research should also focus on genetic improvement and hybrids, prioritizing traits of fast-growth, disease resistance, climate resilience, wood quality and synergies with agricultural crops. Research on acacia, teak, eucalypts and sengon are a high priority in this regard (Carias *et al*., 2022). For example, the development of cold-tolerant clones suited for inland China is recommended for eucalypts, while for acacia improving stem form and productivity remain priorities for the production of higher-value logs suitable for veneers and sawn timber (Arnold *et al*., 2020).

Examples of actions:

- Improve hybrids tailored to the needs of smallholders. An example is provided by Viet Nam, where smallholders achieved a 50–70 percent yield increase with simultaneous higher pest resistance after adopting improved *Acacia mangium* × *auriculiformis* hybrid clones (Nambiar, 2021)

Increased availability of improved planting stock

While the development of improved germplasm is essential, challenges in accessing these planting materials must also be addressed. This includes investment in the production and distribution of high-quality planting material of suitable tree species, including native species, which have been overlooked in past efforts. Developing nurseries and seed banks, as well as improving access to genetically improved, climate change resilient and disease-resistant planting material, can significantly boost the productivity and success of agroforestry systems (van Noordwijk, 2019).

Examples of actions:

- Improve access to high-productivity breeds and clones that are suited to local conditions and market demand (World Bank, in press), notably through collaboration with the private sector, regional knowledge-sharing and transfer of germplasm.
- Focus smallholders' extension programmes on addressing challenges to maintaining productivity over time, including by adopting more sustainable practices that will increase their resilience to climate change and associated biotic and abiotic risks.
- Adopt a systems approach to improving the quality and quantity of tree seedlings through community nurseries. An example from the Philippines demonstrates how a systemic approach relying on capacity building, nursery development, the introduction and overseeing of nursery management standards, as well as scaling through public partnerships, can improve the supply of tree seedlings for smallholder tree-farming (Gregorio *et al*., 2015).

4.1.5 Developing innovative wood products and associated value chains

Value chains and market access

Further research is required to better understand value chains and multi-level market linkages for wood products from smallholder systems (FAO, 2019; van Noordwijk, 2019). Particular attention should be paid to analysing processing technologies, value chain bottlenecks, market dynamics and access, demand patterns, pricing structures, the specifications for different wood products and the role of intermediaries (Race and Wettenhall, 2024). Similarly, identifying how certification and branding affect market access and prices can guide smallholders and cooperatives in adopting practices that meet market standards (Carias *et al*., 2022). Finally, research into the development of equitable industry-farmer partnerships is an important area of study. Successful models will need to address issues of land access, financing and benefit-sharing to support sustainable wood production by smallholders (Race and Wettenhall, 2024).

Examples of actions:

- Increase investments in research, market development and market accessibility.
- Promote the development and adoption of locally appropriate wood-processing technologies for smallholders and producer organizations.
- Strengthen market linkages by supporting inclusive mechanisms such as digital platforms, market fairs and aggregation hubs.
- Establish risk mitigation tools, such as insurance or price stabilization mechanisms, tailored to smallholder timber production cycles.

Innovative products

Innovation research on developing new materials, production processes and sustainable applications for wood-based products from smallholder systems can unlock further potential for these systems. While wood produced by smallholders and used in engineered wood products, such as laminated veneer lumber (LVL) and cross-laminated timber (CLT), can ensure linkages to international markets, innovation research into complementary products can further diversify incomes and reduce risks (Midgley, Stevens and Arnold, 2017). As an example, research into the use of Nyamplung (*Calophyllum inophyllum*) and Pongamia (*Pongamia pinnata*) as biofuels can boost agroforestry systems integrating these species in Indonesia. Nyamplung, a multi-purpose tree intercropped with rice, maize, cassava and peanuts in agroforestry systems on degraded land, also produces non-edible oil seeds that are harvested and processed into biofuel. Research revealed that the steady, multiple income streams make this agroforestry model economically viable, even with 60 percent crop loss (Baral, Leksono and Seol, 2022; Baral, Shin and Murdiyarso, 2023). Similarly, Pongamia, frequently intercropped with food crops, bears oily seeds that can be processed into biodiesel. Product innovation can thus add an important further income stream and

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improve the profitability of an already versatile system with multiple benefits, including wood production (Baral, Leksono and Seol, 2022). Here, the wood-processing industry may collaborate with the construction sector to promote green
procurement policies and counter negative perceptions of wood products. Engaging young generations (e.g. through social media platforms) may prove particularly useful for product innovation.

Examples of actions:

- Fund applied research on smallholder-sourced wood for engineered wood products and emerging bio-based applications.
- Facilitate partnerships with universities, research institutions, industry innovation platforms and producers to co-develop product innovations suited to local contexts and market trends.
- Invest in production design competitions and innovation challenges that engage youth in developing value-added uses of underutilized wood species.
- Stimulate market demand for diverse products.

Public-private partnerships

Public-private partnerships have emerged as a key mechanism to integrate smallholder tree-farming into larger value chains. These partnerships can provide technical assistance, market access and financial support, contributing to a stronger wood production system (Baral, Leksono and Seol, 2022), as seen above in the case of the Binh Minh Agroforestry Cooperative in Viet Nam. Private sector investment in agroforestry-based supply chains, such as those for timber, biofuel and NWFPs, can create sustainable market demand and incentivize smallholders to adopt agroforestry practices (FAO, 2019).

Examples of actions:

- Strengthen the enabling environment for private sector engagement by de-risking investment in smallholder-based wood value chains.
- Facilitate linkages between corporations acting as buyers and groups of smallholder farmers as producers to obtain timber certification and produce for international markets. The Binh Minh cooperative (Case study 7) and the Burapha Agroforestry model (Case study 9) provide insightful examples in this regard.

4.1.6 Integrating high-value smallholder wood production into multifunctional land use systems

Improving agroforestry design

Despite its longstanding history, research on agroforestry systems design remains an ongoing priority. This includes research on context-specific, optimal tree-crop combinations that balance wood and agricultural production, along with the provision of further ecosystem services. Understanding the complex interactions between trees and crops in various ecological zones is essential to identify combinations that maximize both yields and income for farmers (van Noordwijk, 2019). This includes studying how various combinations of trees and crops affect soil fertility, pest and disease occurrence, water use and overall farm productivity (Carias *et al*., 2022). Important taxa, such as bamboo, rubber and dipterocarps, may be the subject of focus in this type of research. Despite a substantial existing knowledge base, further research is also required to develop best practices for managing various agroforestry systems for wood production, including optimal tree spacing, spatial or temporal intercropping arrangements, rotation periods, as well as stand tending and sustainable harvesting techniques (FAO, 2019). Research focusing on the specifics of wood production, including assessing the impact of different management practices on wood yield, quality and overall system productivity, will help smallholders maximize their returns.

Examples of actions:

- Support further field trials and research on promising models for agroforestry wood production that integrate flexibility to market demands and smallholder constraints and preferences.
- Develop and disseminate technical packages outlining good practices in terms of tree-crop combinations, spatial and temporal arrangements, management practices and associated business models for agroforestry wood production under different contexts.
- Strengthen economic assessments of agroforestry systems for wood production through cost-benefit analyses, return on investment studies, and assessments of long-term system resilience and profitability under different management regimes.

Integration of wood production into smallholder livelihood strategies

Integrating the natural and social sciences into planning and research on the socioeconomic impacts of tree-farming on smallholder livelihoods, will further help quantify the benefits of trees on farms and fine-tune the suitability of certain wood-producing systems to local conditions. This involves assessing how tree farming contributes to income diversification, food security, rural employment, income diversification, resilience and market dynamics. Additionally, research should explore the barriers and enablers for smallholders to adopt and scale up tree growing, including land tenure security, access to finance and community engagement (Baral, Leksono and Seol, 2022; Carias *et al*., 2022).

Well-designed smallholder wood production systems that integrate agriculture and silviculture knowledge and practices, focusing on the simultaneous optimization of profits and resilience for farmers, environmental sustainability, climate change mitigation and adaptation, biodiversity, and soil and water conservation,
incentivize sustainable land management through their compatibility with the livelihood strategies of rural communities. Promoting NWFPs in agroforestry systems and developing simple value-addition technologies can substantially enhance profitability and reduce vulnerability, as demonstrated by the Thai agroforestry system referred to as "three types of trees to provide four benefits".[4]

Examples of actions:

- Encourage research and digitalization focused on optimizing species combinations, planting designs and technological innovations.
- Assess existing livelihood strategies and land use systems and introduce compatible innovations focusing on wood production (e.g. the integration of timber trees into existing homegardens in Indonesia (Catacutan *et al*., 2017)

Environmental and climate benefits

Knowledge gaps relating to ecosystem service benefits call for further research to quantify the contribution of various agroforestry systems towards the achievement of global environmental and climate goals (van Noordwijk, 2019). Research on the contributions of trees in agricultural landscapes to climate change adaptation and resilience will help further unlock the potential of smallholder tree production systems (Lin *et al*., 2021; Telwala, 2023). Research on climate change adaptation and mitigation benefits should include a focus on improving the socioeconomic conditions of concerned smallholders (Mbow *et al*., 2014). Investigation into the long-term impacts of agroforestry on landscape restoration and ecosystem resilience (Carias *et al*., 2022), or the use of agroforestry as a nature-based solution to adapt to climate change (Telwala, 2023), can provide evidence to support scaling up these practices across the region. Linked to this, research into the potential of PES, the development of methods to quantify carbon storage in agroforestry systems and the establishment of monitoring frameworks to support PES schemes, can help unlock

[4] "The three types of trees, which are trees for use at home, trees for edible products and trees for commercial timber, provide the four benefits of shelter, resources, food, as well as the restoration and conservation of the environment and ecosystems – together this provides a model for reforestation". wwf-scp.org/reforestation-in-chiang-mai

an additional income stream for smallholders (FAO, 2019). Additionally, research on the context-specific and quantified impacts of smallholder wood production systems on soil and water resources and microclimatic conditions will help improve the design of such systems.

Examples of actions:

- Develop carbon forestry projects suited to the special conditions of smallholders operating alone or in cooperatives.
- Develop other types of PES schemes for smallholder wood production systems generating water, tourism, erosion control or other types of ecosystem services.
- Develop risk-based and/or climate insurance products that reflect the risk-mitigating effects of smallholder wood production systems, including agroforestry.
- Reflect diverse agroforestry systems in the development of biodiversity credit systems.

4.1.7 Creating long-term models for sustainable, inclusive and resilient production

Tropical tree crops

The potential of tree crops to supply tropical timber markets in the future will depend on improvements in timber quality and increased knowledge of wood properties. Tree crop plantations have significant potential for industrial roundwood production in tropical regions (FAO, 2022a) once they reach the end of their production cycle, particularly when certified. Additional potential to increase wood supply lies with tree crops grown in agroforestry systems, but scaling these models requires strong partnerships with the private sector and research organizations to address logistical bottlenecks (World Bank, in press).

The wood supply from tree crops is expected to increase significantly in the coming years as plantations reach the end of their lifecycle. Rubberwood currently accounts for 17 percent of total roundwood production in the Lower Mekong Subregion, with production expected to double in the next 20 years, adding 32 million m^3 of roundwood equivalent (RWE) to the region's current wood supply (World Bank, in press). Thailand remains the dominant producer of rubberwood, but Cambodia and Lao PDR should experience the most significant relative growth, with their rubberwood production multiplying by a factor of ten over the next 20 years.

In addition to rubberwood, other tree and nut crops, such as cashews in Cambodia, could generate 6.5 million m^3 of firewood annually by 2040, when the old plantations are replaced. In addition to firewood, their wood is often used for furniture-making or for household use. Wood waste from these tree crops (e.g. prunings or tree trunks), often available in large quantities in rural areas, could provide an excellent feedstock for biofuel production (Putra, Veza and Irianto, 2024). Other applications could include the replacement of woodchips by wood waste in particleboard (Lee *et al*., 2024).

Examples of actions:

- Engage in collaborative and international research programmes on wood properties, wood residue management and the valorisation of tree crops.
- Facilitate knowledge transfer to extension staff and producers' organizations on existing good practices of rubberwood management, and other promising tree crops for wood supply (e.g. coconut).

Smallholder tree-farming and mosaic landscape restoration

A priority area is research on integrated and climate-resilient landscape management approaches that focus specifically on incorporating small-scale wood production systems into wider spatial contexts. It is essential to understand how these systems can be integrated harmoniously within broad mosaic landscapes, including a variety of land uses, to optimize wood supply and enhance ecosystem services at different spatial scales (FAO, 2019). This aspect has acquired increasing importance with the implementation of national goals and commitments towards forest and landscape restoration (FLR) across the region (IUFRO 2020), a momentum further supported by the ongoing United Nations Decade on Ecosystem Restoration (2021–2030). The upcoming United Nations Decade on Afforestation and Reforestation (2027–2036) can be expected to place an even stronger focus on the integration of trees into agricultural landscapes, especially in agroforestry systems, to increase the sustainable production of wood and NWFPs, while empowering smallholders and improving their livelihoods.

Research on transitioning smallholder wood production systems, focused on single commodities and providing few co-benefits, towards complex, more sustainable and resilient systems, will provide important lessons for the restoration of vast landscapes, such as those used for palm oil and rubber production (Octavia *et al*., 2022). Research into the effects of government policies on plantation expansion, market access and land use is needed to identify effective policy interventions that could encourage sustainable plantation development (Arnold *et al*., 2020), contributing to balanced, multifunctional functional landscapes providing a varied range of economic, social and environmental benefits. Forest-based companies are displaying growing engagement in restoration, as shown for example by the Forest and Climate Leaders' Partnership (FCLP) or the Advisory Committee on Sustainable Forest Industries (ACSFI). Their commitment to facilitating the fair and inclusive participation of small-scale tree farmers will be essential to enable the implementation of people-centric restoration efforts that contribute to rural development.

Examples of actions:

- Integrate ecological restoration targets into commercial plantation concessions through a landscape approach based on forest integrity (World Bank, in press).

Strengthening the resilience of smallholder tree-farming systems

More diverse production systems provide smallholders with multiple income sources, reducing their vulnerability to climate risks and market fluctuations (Baral, Leksono and Seol, 2022). Smallholder tree farmers focusing on wood production as a main source of income face external uncertainties and risks related to trade. These may affect the industries and stakeholders they work with and that connect them to international markets, and include prices fluctuations, changing market requirements or other shocks, such as the COVID-19 pandemic. For example, the upcoming application of the European Union Regulation on Deforestation-free Products and its stringent requirements pose a risk for smallholders' income in Southeast Asia and their position in the supply chain (Melati, Jintarith and Lee, 2024).

Small-scale producers with a high level of specialization in wood production may focus on a narrower range of tree species, such as acacia and eucalypts, that can display limited resilience to certain biotic or abiotic risks. For example, the incidence of pest and disease in Acacia and Eucalyptus stands has increased globally over time. More diverse systems, such as mixed-species plantations, are reported to have better resistance to insect pests as well as presenting other ecosystem services and benefits (Jactel, 2023).

In Viet Nam, loss of productivity from pests and diseases continues to be a problem (Pham *et al*., 2021), but the mixed-species approach, combining fast-growing trees for global markets with native species for local use, has stabilized demand-side fluctuations. Mitigating the multiple risks faced by smallholder tree farmers, and strengthening their resilience and adaptive capacity, could build on an integrated approach that promotes adapted practices, diversified systems and species, while concomitantly focusing on the development of domestic wood markets locally, including for a wider range of wood products allowing for local value addition.

Examples of actions:

- Diversify opportunities on domestic wood markets and value addition for domestic wood use.
- Support research into risk management strategies, including the diversification of tree species and products to support risk management while ensuring year-round flows of benefits (van Noordwijk, 2019). For example, research on climate risk could focus on identifying appropriate acacia planting stock for cold weather and typhoon-prone locations, along with risk mitigation strategies for smallholders in both coastal and inland China (Arnold *et al*., 2020).
- Capitalize on data and information on mixed-species plantations to support the alleviation of barriers such as higher establishment costs, lack of technical knowledge and market preferences for uniform timber.

4.2 Conclusion

Smallholder tree-farming in Asia and the Pacific encompasses a gradient of diverse and carefully crafted strategies. These are elaborated and adopted by smallholders to meet their individual needs, constraints and preferences, within specific contexts, which are ecological and biophysical as well as political, economic and socio cultural in character.

Over the past decades, this vibrant and fruitful environment has benefited from a wealth of research, practical experience, and policy and donor support – in recognition of its high potential to meet market demands and development objectives. It has also experimented with varied multistakeholder arrangements, leveraging partnerships with a whole range of players along the supply chain, delivering on their wood production objectives while contributing to rural poverty alleviation.

In a rapidly evolving world, where local and global scales are increasingly connected and national economies are becoming more specialized, new challenges are arising for smallholder tree-farming. Smallholders are exposed to emerging threats as their reliance on single markets or commodities increases their vulnerability to external and sometimes unpredictable requirements, or to other shocks and biotic or abiotic risks. However, a broad range of opportunities are also available to smallholder tree farmers, with the simultaneous emergence of a forest-based bioeconomy, increasing momentum towards global forest and landscape restoration, and growing societal concerns about consumption patterns and impacts.

While the topic has been widely studied and supported, the strategies implemented and the lessons learned across decades of experimentation can now be used to strengthen multiple facets of smallholder tree-farming in Asia and the Pacific. Sustained institutional and technical assistance as well as support for new models of multifunctional tree-farming systems can bring about income and stability to producers and their communities while also contributing to the resilience and sustainability of wider ecosystems.

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Case studies

Case study 1. National Agroforestry Policy, India

Core information

Partners	• Government of India • Indian Council of Agricultural – Central Agroforestry Research Institute (ICAR-CAFRI) • Centre for International Forestry Research and World Agroforestry (CIFOR-ICRAF)
Location and context	India has a long history of agroforestry as part of traditional land management practices. Indeed, the country has been actively involved in agroforestry research since its beginning over 40 years ago. However, prior to 2014, there was no comprehensive technical or institutional support for agroforestry in the country, and no ministry held a mandate. Agroforestry generally fell through the cracks of policy domains – a problem that is not unique to India and is reflective of agroforestry's multifaceted nature at the intersection of the agriculture, forestry, environment and rural development sectors.
Key details	Recognizing the need to address these structural challenges, the Ministry of Agriculture, Cooperation and Farmers' Welfare, with support from CIFOR-ICRAF, was tasked with developing a National Agroforestry Policy (NAP). Launched in 2014, the intersectoral policy aimed to remove barriers and strengthen the enabling environment for scaling up agroforestry. Its key objectives are to enhance productivity through agroforestry and meet growing domestic demand for timber, food and NWFPs. This includes fulfilling the raw material requirements of wood-based industries and reducing wood imports, in addition to reducing pressure on existing forests by producing fuelwood, fodder and NWFPs through agroforestry.
Approach and activities	The NAP bridged various sectors of natural resource management, expanding existing mandates and programmes on agroforestry. The policy facilitated the simplification of regulations for harvesting, felling and transporting trees grown on farmlands. It also recommended the introduction of a database of land records and a market information system to secure land tenure and improve market access. By providing a common platform, the policy empowered stakeholders to collaboratively plan, set priorities and develop strategies. This approach enhanced interministerial coordination, programmatic alignment, financial and institutional resource mobilization, capacity building, and technical and other types of support.
Agroforestry system	**Typology: Multiple** The policy does not promote a single agroforestry system but rather focuses on increasing the productivity of barren community and other degraded lands. Each state is responsible for identifying the focal tree species of particular relevance to their context.
Wood production context	The Indian timber market relies heavily on four key sources: 1) harvesting by state forest departments, 2) forest development corporations, 3) privately managed tree-growing areas collectively known as trees outside forests (TOF), and 4) imports. The NAP sought to increase supply coming from TOF and agroforestry systems while reducing the growing share of rising demand being fulfilled through imports. India's wood-based industries play a vital role in supporting the rural economy by generating both permanent and seasonal employment opportunities.
Main wood production purpose	The NAP prioritizes wood production to meet national demand, including subsistence needs, in order to reduce pressure on natural forests. Trees outside forests, including in agroforestry systems, play an especially crucial role in supplying raw materials for India's plywood, panel, pulp and paper industries. Deciduous species like eucalyptus and poplar are the main contributors. Approximately 4 million tonnes of the country's paper production are wood-based, with the majority of raw materials coming from agroforestry and farm forestry programmes (Kant and Nautiyal, 2021).

Wood production and wood-based value chains

Wood-based agroforestry value chains and production details	The NAP has played a pivotal role in increasing the total number of trees planted outside forests, with the Forest Survey of India recording a substantial rise in coverage of 88.7 million cubic metres one year after implementation. Currently, agroforestry is practised on over 28.42 million ha of land across India (Arunachalam *et al*., 2022). Trees outside forests, including those from agroforestry systems, supply 93 percent of India's annual timber demand and nearly half of its woodfuel. India's total roundwood production stands at approximately 47 million cubic metres annually. Of this, only about 2 million cubic metres come from state-owned forests, where harvesting is strictly limited. The remaining 45 million cubic metres are sourced primarily from TOF (Ramanan, Arunachalam and Handa, 2023).

Outcomes

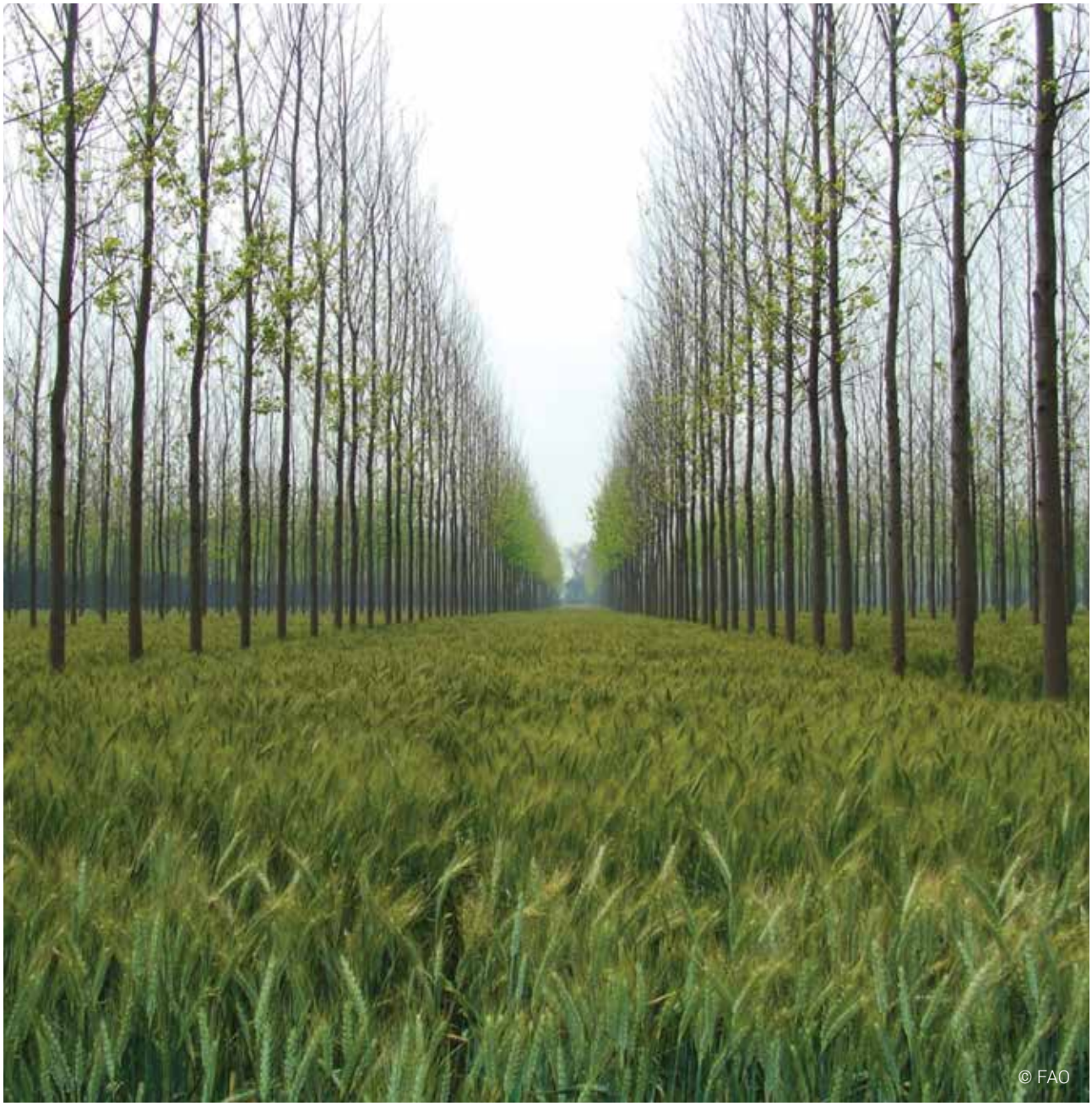
Economic viability and other socioeconomic benefits	The simplification of regulations in the timber industry has fostered a more equitable and self-sustaining value chain. The NAP has also engendered various monetary and non-monetary incentives to boost agroforestry adoption. In 2016, the Government of India approved a dedicated agroforestry budget of USD 150 million for the first time – a significant financial commitment to the sector (FAO, 2024). The existence of strong policy support for agroforestry has also triggered investment in technologies to assist uptake, such as numerous mobile applications.
Environmental co-benefits	The NAP supports India's commitments under its National Determined Contributions (NDC) (Arunachalam, Ramanan and Handa, 2024).
Social viability and inclusiveness	The policy has strengthened national research and development institutions, integrated agroforestry into the Corporate Social Responsibility Act and established the National Sub-Mission on Agroforestry.

Lessons learnt and recommendations

Enabling conditions	The establishment of coordination mechanisms and agroforestry-related commissions at national levels supported the implementation and monitoring of the policy. The NAP facilitated changes in regulations, such as easing restrictions on the felling and transportation of trees grown on farms, which directly impacted the availability of timber and wood from agroforestry. It also reduced the burden on farmers seeking to grow trees and sell wood.
Challenges and lessons learnt	The policy's emphasis on supporting wood-based industries meant that industrial models of agroforestry for wood production were prioritized, leaving other components (i.e. crops and animal husbandry) inadequately addressed. As a result, provision for smallholder concerns, such as reduced agronomic yields after tree canopy closure, is insufficient, which can disincentivize tree planting. Additionally, traditional systems like homegardens, parklands and silvopastoral systems – often referred to as "Cinderella agroforestry systems" (Nair, Viswanath and Lubina, 2017) – are not explicitly included in the policy and could have benefited from policy support. Inadequate availability of quality planting material is another persistent challenge. Agroforestry's environmental services could also profit from greater recognition with provision for mechanisms like payment for ecosystem services (PES). The absence of a dedicated extension network for agroforestry at the state, district and sub district levels limits implementation. To address this gap, ICAR-CAFRI has developed an Agroforestry Extension Framework. Value addition and market linkages for agroforestry products are also in need of greater development.

Lessons learnt and recommendations *(continued)*

Recommendations for scaling-up	To effectively scale up agroforestry, a decentralized institutional framework adaptable to various land types and responsive to specific socioeconomic and climatic conditions should be established. Increasing the number of trained agroforestry extensionists and creating Centres of Excellence could enhance capacity building across regions. Additionally, improving nursery accreditation and certification processes for quality planting material is crucial for sustainable scaling up. Strengthening partnerships with the private sector, in order to align a portion of their Corporate Social Responsibility (CSR) initiatives with agroforestry and to the development of scalable, bankable agroforestry models, is a critical avenue. As the first country in the world to develop a national agroforestry policy, India paved the way for other countries to develop their own. Developing national policies and strategies is one of the key pathways for creating enabling environments and sustainably scaling up agroforestry.
Acknowledgements	This case study was developed with the valuable contributions and support of Ayyanadar Arunachalam, Director, ICAR – Central Agroforestry Research Institute, and Shiv Kumar Dhyani, Interim Country Director for India, CIFOR-ICRAF.



Case study 2. Improving legality for smallholder teak producers, Thailand

Core information

Partners	Regional Community Forestry Training Center for Asia and the Pacific (RECOFTC)
Location and context	Nan Province, located 700 km north of Bangkok, is home to a vital forest ecosystem that sustains the Chao Phraya River, the country's largest watershed. Approximately 40 percent of the water originates from the Nan River; however, over the past three decades, more than 160 000 ha of forest in Nan have been degraded, threatening both water quality and water availability in the Nan and Chao Phraya rivers (RECOFTC, 2022).
Key details	Thailand aims to increase forest cover to 40 percent of the country's land area by 2036. Smallholders are expected to play a key role in this endeavour through tree planting and sustainable timber production on public lands. However, several challenges hinder their participation, including delays in public land allocation and a complex legal framework governing tree planting, timber harvesting, transportation and trade. To address these barriers, RECOFTC piloted innovative solutions in Nan Province aimed at streamlining smallholder participation in sustainable forestry. These efforts focused on clarifying the legality of smallholder teak production and establishing transparent supply chain controls to ensure compliance and sustainability. One such initiative, FLOURISH (2018–2022), demonstrated that farmers can implement community-based supply chain controls, incorporating documentary evidence and traceability systems to verify the legality of teak grown on public land.
Agroforestry system	**Typology: Woodlots/Buffer zones** Smallholder teak plantations in buffer zones around conservation forests.
Approach and activities	In Santisuk District, Nan Province, RECOFTC worked with 13 smallholders to register their teak plantations under the Forest Plantation Act, securing harvesting permits and proving the legality of their timber on Sor Por Kor land (government-allocated agricultural land). This involved creating an online and paper-based database that documented land tenure, plantation boundaries and tree-specific data, such as location, size and species. The resulting maps and timber inventories enabled farmers to assess production capacity and plan sustainable plantation management. The community-based supply chain control system ensures traceability across timber sourcing, transport, processing and trade. It uses official documentation to verify that the timber comes from legally registered plantations, preventing illegal logging from conservation forests. RECOFTC also collaborated with the provincial Royal Forestry Department and the Ministry of Natural Resources and Environment to assist farmers on Kor Tor Chor land (communal plots managed jointly by communities under government schemes for sustainable land use) in obtaining teak harvesting permits. Key activities included helping farmers demarcate land boundaries, document timber species on their land and complete the official procedures required under the Forest Act. While these permits grant the farmers the right to harvest and use the timber, they do not extend to transportation or other downstream processes. Training sessions were organized for local communities on market analysis and the development of income-generating enterprises. These sessions equipped participants with the skills needed to maximize economic benefits from sustainable forestry initiatives while fostering long-term forest restoration goals.

Wood production and wood-based value chains

Wood production context	Thailand's domestic wood supply relies heavily on plantation species such as teak and eucalyptus, as well as agricultural by-products like mango, durian and rubber wood – the latter being the largest contributor. Despite these resources, Thailand remains a major importer of timber as persistent raw material shortages challenge the country's wood-based industries, which are striving to meet rising domestic demand. Domestic consumption is mostly driven by the construction, furniture and handicraft sectors. High-value woods like teak also contribute to exports, particularly to Asia, Europe and the United States, where Thai teak is renowned for its quality and sustainability. However, exports remain limited compared to local consumption due to constraints on scaling sustainable production and stringent regulations on natural forest logging.
Main wood production purpose	Cultivated teak is sold generally to local processors for timber processing and furniture production, contributing to local timber markets and, in some cases, regional or international trade.
Wood-based agroforestry value chains and production details	In Nan Province, the timber value chain is supported primarily by small-scale operators, including timber-processing workshops and furniture makers. These businesses often rely on timber sourced from other provinces, such as Phrae, due to limited local production. Wood processors typically purchase timber that is over 15 years old with a growth diameter exceeding 50 centimetres. Transactions are conducted based on standard pricing set by the Royal Forest Department, with timber purchased by the cubic metre.

Outcomes

Economic viability and other socioeconomic benefits	Proving the legal origin of timber grown on public land has significantly increased farmers' confidence. One outcome has been the creation by farmers of a collective logging group, improving their knowledge of plantation management and securing fair and standardized prices for their timber. The producers' group is now planning to enhance the value of their timber by establishing a local sawmill for lumber processing and partnering with private sector companies to produce wooden products.
Environmental co-benefits	The project has emphasized the adoption of low-impact harvesting practices to reduce environmental degradation during timber extraction. These practices include techniques that minimize soil erosion, preserve surrounding vegetation and protect water resources, contributing to the overall health of the ecosystem. By promoting responsible forestry management, the initiative helps maintain biodiversity and ecological balance within managed forests. Efforts have also been made to minimize the carbon footprint associated with timber transport.
Social viability and inclusiveness	The FLOURISH initiative supported communities in securing clearer and more secure land rights, which is a critical step toward long-term social and economic stability. By assisting smallholders in registering their teak plantations and obtaining formal harvesting permits, the project empowered participants to engage in legal and sustainable forestry practices.

Lessons learnt and recommendations

Enabling conditions	Thailand has developed a legal and policy framework aimed at protecting and restoring its forests while promoting sustainable resource use and supporting livelihoods. A key policy driver is the 12th National Economic and Social Development Plan, which set a goal of 40 percent forest coverage. This target includes 25 percent designated as conservation forests and 15 percent as economic forests, balancing ecological preservation with sustainable resource use. Recognizing the role of smallholders in forest management, the government also introduced legal reforms to encourage tree planting for economic purposes. Key milestones include the National Land Policy Committee Act, the Forest Act, the Forest Plantation Act and the Community Forest Act. These measures aim to clarify legal frameworks, improve land tenure security and offer incentives to enhance smallholder participation in sustainable forestry initiatives.

Lessons learnt and recommendations *(continued)*

Challenges and lessons learnt	Despite government efforts to promote teak cultivation, several broader challenges continue to hinder smallholder participation and long-term investment in the sector. The slow, complex process of public land allocation, coupled with tenure insecurity, pushes farmers towards faster-growing crops like maize. The 25-year maturation period for teak adds to the uncertainty, making it less appealing for smallholders. Even when granted land access, smallholders face significant legal and procedural hurdles for harvesting and selling timber when compared to private landowners. Additionally, limited knowledge, skills and resources related to sustainable management – such as planting, thinning and pruning – often result in lower-quality timber and lower market prices. The FLOURISH Initiative has made progress in addressing these issues but the small scale of these efforts highlights the need for broader support. Scaling up these experiences could remove critical barriers and enable smallholders to make teak cultivation a viable livelihood option while advancing Thailand's forest restoration goals.
Recommendations for scaling-up	Based on the experience with this initiative, several measures were recommended to enhance smallholder participation in legal timber production and trade. Simplifying regulatory processes is a priority, including streamlined plantation registration systems and procedures for obtaining permits to harvest, process and transport timber. Reducing bureaucratic barriers would encourage greater investment and participation in sustainable forestry. Financial incentives and subsidies should be introduced to attract investment to the teak sector, helping to offset the high upfront costs of plantation establishment and maintenance. Mechanisms for career development in sustainable logging on public land are also essential, as these can encourage skilled labour and long-term engagement in the sector. To scale up proven approaches, community-private sector partnerships, like those implemented in Santisuk District, could be replicated across Thailand and expanded to include other tree species and NWFPs. Neutral facilitation will be critical in building trust and ensuring alignment between stakeholders, particularly as partnerships expand. These actions will help foster a more inclusive, sustainable and scalable approach to smallholder forestry.
Acknowledgements	This case study was developed with the valuable contributions and support of Warangkana (Nok) Rattanarat, Thailand Country Director, RECOFTC, and Ronnakorn Triraganon, Senior Strategic Advisor, RECOFTC.

Case study 3. Improvement and management of teak and sandalwood, Papua New Guinea

Core information

Partners	• Australian Centre for International Agricultural Research (ACIAR) • University of the Sunshine Coast
Location and context	The project focuses on the East New Britain Province, Central and Gulf Provinces in Papua New Guinea (PNG), where agriculture and subsistence activities dominate livelihoods.
Key details	In many parts of Papua New Guinea (PNG), smallholders struggle with limited access to adequate timber resources and a lack of commercial opportunities, both of which are critical for sustaining secure livelihoods. Smallholder teak production has been hindered by the scarcity of high-quality seed supply, while the availability of natural sandalwood has declined. However, existing markets for wild-harvested sandalwood and reliable demand for sawn teak locally provide strong economic potential for smallholder growers. To address these challenges and maximize the potential of these species, this project aimed to improve germplasm sources for teak and sandalwood, develop viable smallholder silviculture models and build community capacity for sustainable wood production.
Agroforestry system	**Typology: Woodlots** Trials explored different ways to grow teak *(Tectona grandis)* and sandalwood *(Santalum macgregorii)*. **Teak trials focused on spacing to test growth and uses:** • Close spacing (2 × 2 m, 2 500 trees/ha) is ideal for producing poles. • Routine spacing (4 × 4 m, 625 trees/ha) is the standard approach. • Wide spacing (6 × 6 m, 277 trees/ha) is suitable for combining teak with other crops in agroforestry systems. **Sandalwood trials were planted on two sites:** • **Site 1:** A 0.8-ha area used a 4 × 4 m grid to grow sandalwood of three species and six seed sources alongside two host species, *Acacia crassicarpa* and *Acacia auriculiformis*. The acacias were arranged in double rows (4 m × 12 m) with two rows of sandalwood between them • **Site 2:** 500 sandalwood trees were planted on 0.5 ha with spacing of 6 m × 3 m. Host species were added after every four sandalwood trees. Initially, farmers planted peanuts, cassava, sweet potato and pineapples between the trees for household use. However, after the first crop cycle, the site became overgrown with kunai grass *(Imperata cylindrica)* preventing further cultivation.
Approach and activities	The project made available germplasm resources, conducted training and developed financial models for teak and sandalwood smallholders. Over 22 500 teak trees were planted across 36 ha, and sandalwood woodlots were established in family and sub-clan settings. **Teak** • The establishment of a diverse array of provenance plots served as a foundation for selecting superior trees and developing seed production areas to ensure high-quality germplasm for future use. • Cost-effective nursery techniques for teak were introduced in East New Britain Province utilizing bare-root stump production in ground beds, which minimized capital requirements. • These accessible methods led to the establishment of 38 community nurseries by landowners. **Sandalwood** • The project evaluated *S. macgregorii* trees across five populations in PNG's Central, Gulf and Western provinces. Trees from different provinces presented distinct properties, enabling the selection of high-value germplasm. These improvements have the potential to enhance the commercial value of new plantings, boosting farmers' incomes.

Wood production and wood-based value chains

Wood production context	Teak, an exotic hardwood in PNG, and sandalwood, a rare native species, are both prioritized for research and development by the Government of PNG. These species are highly valued due to their strong local and international demand, high market value and trade feasibility at small scales. Teak, known for its robust growth in PNG, produces high-quality timber prized in global markets and valued locally for its durability in house construction. Conversely, sandalwood presents a unique niche market opportunity, with its distinctive oil characteristics and potential for organic local production making it highly sought after in global markets. However, maximizing its commercial potential requires careful genetic selection to optimize heartwood and oil yield, as well as precise species identification to meet market standards. The quality and composition of sandalwood oil are key determinants of its market appeal.
Main wood production purpose	Teak is grown primarily for high-quality construction timber while PNG sandalwood is cultivated for its high-value oil. The project highlighted the robust local demand in East New Britain for teak thinnings, such as posts, as well as durable sawn timber. Currently, PNG plantation teak is exported to India at an average under-sap price of K 800/m^3 (USD 250). Domestically, the market for sawn timber is even stronger, with prices ranging from K 1 000 to K 2 000/m^3, often exceeding export rates. An estimated 1 100 new permanent homes are expected to be built annually from 2045 onwards, based on a 25-year teak rotation. Smallholder-grown teak has significant potential to meet timber demand for this market. The project demonstrated strong enthusiasm among landholders for restoring sandalwood resources by integrating replanting efforts into agroforestry systems.
Wood-based agroforestry value chains and production details	Early production benefits emerged from pruning and thinning the teak woodlots. Small round poles were used for constructing outbuildings, particularly market houses along the main road, and were also sold at local markets. A total of 140 posts measuring 3 m, derived from one of the teak clonal trials (0.92 ha), were sold for PGK 2 100 (AUD 835) in year 6. As the trees begin to mature and produce seeds, some families are also earning returns from commercial teak stump production.

Outcomes

Economic viability and other socioeconomic benefits	**Teak.** The revenue generated from the sale of thinning material and sawn timber was calculated using a financial model for a full rotation of 20 years. At a discount rate of 7 percent, the Net Present Value (NPV) was found to be PGK 18 212 per ha at year 25, with a return on labour of PGK 342 per day and an Internal Rate of Return of 23.5 percent. **Sandalwood.** A financial model for sandalwood was developed based on a stocking rate of 232 sandalwood seed trees and 168 long-term host plants per hectare. The model also included provision for the presence or absence of agricultural crops produced in the first four years. At a discount rate of 7 percent, and using the most likely product prices, the NPVs were PGK 17 033 and PGK 24 427 for the woodlot planting and agroforestry planting models, respectively. The respective Internal Rates of Return (IRR) were 15 percent and 24 percent. The most likely return to labour is PGK 56 and PGK 69 per day for the woodlot and agroforestry plantings, respectively. This return to labour exceeds the PNG minimum wage of PGK 24 per day.
Environmental co-benefits	The project's farmer extension activities and demonstration plots sparked local commercial demand for sandalwood seeds, creating an emerging market that assigns economic value to mature standing trees. This development has the potential to reduce harvesting pressure on the limited number of remaining seed trees. Indeed, the planting of sandalwood seedlings in Iokea and Kairuku represents a significant step toward environmental conservation. Although the number of seedlings planted is modest, it signifies a positive shift in the species' conservation prospects. To preserve genetic diversity, the project emphasized seed collection from a broad range of mother trees. Forest Authority officers were trained in this approach and are now actively disseminating this knowledge to collaborators in Iokea and Girabu, as well as to key sandalwood growers in Kairuku.

Outcomes *(continued)*

Social viability and inclusiveness	During project workshops, women showed an almost universal interest in participating in smallholder forestry initiatives. In East New Britain, where matrilineal land tenure is prevalent, four workshops with women smallholder farmers highlighted their keen interest in planting trees on their land. However, the participants identified several barriers, including limited knowledge and access to information, competing responsibilities, challenges in mobilizing labour and restricted access to suitable land. Addressing these challenges will require targeted research and tailored support to empower women in agroforestry.

Lessons learnt and recommendations

Enabling factors	Key enabling conditions for this research project and its broader impacts include strong local and international demand for teak and sandalwood and existing interest among smallholders. The project also aligned with the Government of PNG's national research and development priorities.
Challenges and lessons learnt	The project revealed a strong interest among smallholders in planting trees, driven by the potential for future income and the need for construction materials. Limited knowledge of woodlot management was identified as a key barrier to adoption, however, prompting the project to assess training needs and preferences among smallholders. While respondents acknowledged gaps in their knowledge of timber tree planting and management, many had experience in managing other tree crops such as cocoa, coconut and fruit. This existing expertise was leveraged through targeted training and extension programmes to quickly enhance their skills, confidence and capacity in nursery production and tree cultivation. Sandalwood plantings were implemented at three levels: family, subclan and clan. Both family and subclan-level plantings demonstrated productive outcomes. In contrast, the clan-level planting faced challenges due to complex social dynamics, leading to maintenance issues and interference. The family-level approach proved most effective, as it simplified land ownership, woodlot management and benefit-sharing processes, ensuring smoother implementation and higher success rates.
Recommendations for scaling-up	For teak, the nurseries and woodlots were established with seeds and technical guidance provided by the project, while growers contributed land and labour. Although adoption rates were initially modest, the growers' ability to independently establish woodlots without financial support has proven to be a sustainable model, offering significant potential for scaling up as local seed supplies expand. In order to realize the potential of meeting local timber demand, it is essential to establish a functional coordinating organization, such as a producers' group or an institutional processor (e.g. out-grower schemes). For long-term sustainability, this organization would require a reliable funding model, an ethical framework to build trust with farmers, and well-trained staff to support operations and service delivery. Its design should account for the geographic distribution of woodlots, prioritizing Wards or local-level governments with sufficient land to achieve economies of scale through a critical mass of smallholder woodlots. Developing a sustainable sandalwood sector in PNG also demands strong institutional and regulatory support. Key recommendations that emerged from the project include: 1) imposing a ten-year trade moratorium to allow for natural population recovery; 2) creating a grading and sales registry for transparency and monitoring; 3) reallocating sandalwood tax revenues to the PNG Forestry Authority for enhanced oversight; and 4) promoting restoration through family gardens, boundary plantings and enrichment initiatives.
Acknowledgements	This case study was developed with the valuable contributions and support of Nora Devoe, Research Programme Manager, Forestry, Australian Centre for International Agricultural Research (ACIAR).

Case study 4. Innovative coconut-wood products, Fiji

Core information

Partners	• Australian Centre for International Agricultural Research (ACIAR) • Department of Primary Industries, Fiji
Location and context	This project is based in Fiji, with broader impacts planned for the Pacific region. The coconut estate in the Pacific, consisting of 65 000 ha in Fiji and 590 000 ha in other countries, faces challenges due to ageing palms that require renewal.
Key details	This ongoing research project aims to address this challenge by developing wood-processing technologies to transform coconut and other currently low-value forest resources into high-value engineered wood products (EWPs) suitable for local and international markets. This transformation is intended to increase returns for farmers, enhance coconut estate renewal, support a sustainable forest products industry, boost employment and expand trade in the Pacific.
Agroforestry system	**Typology: Woodlots/intercropping** The initiative focuses specifically on coconut palms rather than integrated agroforestry systems. However, coconut stands play a crucial role in traditional Pacific agroforestry systems, serving as a critical food source while also providing shade for various food and cash crops.
Approach and activities	The research seeks to develop and validate wood-processing technologies to transform coconut and other low-value forest resources – often regarded as waste disposal burdens – into high-value EWPs. The project aims to create market demand for coconut stems, providing farmers with incentives to remove ageing and low-productivity palms. This process facilitates the sale of senile stems, and also supports and offsets the costs of replanting, ultimately enhancing coconut productivity. A previous ACIAR project demonstrated that senile coconut stems and other small-diameter logs can be efficiently processed into quality veneer using spindleless lathe technology, achieving higher recovery rates than traditional processing systems like sawing. This method conserves raw materials, improves economic efficiency and produces veneers suitable for high-value EWPs. Despite progress in peeling techniques, further research is needed to optimize stages like grading, drying, gluing, pressing and finishing. The project focuses on advancing technological and product innovations in EWP manufacturing through: • log processing techniques and equipment optimization, • specialized adhesion technologies, • product design and manufacturing enhancements, • preservation and protection systems, • residue management strategies. The project also included research to identify how participation in the proposed value chain may impact women and men in different ways and to ensure gender-equitable sourcing of senile coconut stands.

Wood production and wood-based value chains

Wood production context	Fiji serves as the central hub for veneer and plywood production in the Pacific, with established processing infrastructure already in place. However, mills in Australia, Fiji and across the Indo-Pacific region are currently underutilized. Expanding the supply of feedstock could significantly improve the operational efficiency and economic viability of these businesses.
Main wood production purpose	The EWPs are intended for local and international markets – both useful structural and architectural EWPs for domestic consumption as well as export-suitable, high-value products contributing to trade and economic growth.

Wood production and wood-based value chains *(continued)*

Wood-based agroforestry value chains and production details

The benefits of this research are intended to span the entire value chain, from farmers to export markets. They will create urban and rural employment opportunities for both women and men, provide valuable structural and architectural EWPs for domestic use, and generate high-value export products that contribute to trade and economic growth. EWP-manufacturing industry partners will target specific supply segments, with the three Fijian partners focusing primarily at first on peeling coconut stems, while the Australian firms concentrate on processing hardwood and softwood thinnings.

Preliminary economic analysis indicates that a single veneer lathe operation, processing 15 000 m^3 of logs annually, could be sustained by utilizing approximately 27 000 coconut or other tree stems per year. With the available volume of senile coconut palms in Fiji alone, there is an opportunity for several processing operations to operate simultaneously over the long term.

Outcomes

Economic viability and other socioeconomic benefits

Preliminary estimates further show that:

- At a price of AUD 40/m^3, farmers supplying logs for a single operation could collectively earn approximately AUD 600 000 annually.
- A single operation would create 26 full-time processing and manufacturing jobs, with additional employment opportunities in log harvesting, transportation, sales and marketing.
- The facility would produce around 7 500 m^3 of veneer annually, with a potential market value of AUD 6 million.

Initially, income from selling senile coconut stems may be modest for farmers. However, as coconut-based EWPs enter commercial production, sustained demand is expected to provide farmers within the economic haul distance of manufacturers with a consistent income boost.

The greatest economic benefit will come from improved profitability through coconut estate renewal. By creating value from previously discarded senile stems, this research has the potential to enhance the incomes of over half a million Pacific households that depend on coconuts for their livelihoods.

Environmental co-benefits

Coconuts play a critical role in environmental management across the Pacific Islands. Commonly found along coastlines, coconut trees and other littoral vegetation act as natural barriers, protecting infrastructure and inland resources from erosion and storm surges exacerbated by extreme winds and tides linked to climate change. Healthy coastal and coconut forests, with their tall stems and multi-layered canopies, help regulate microclimates, benefiting nearby crops and contributing to climate change adaptation.

Removing senile stems will help renew the coconut estate and reduce on-site debris, which serves as breeding grounds for coconut rhinoceros beetles, a destructive pest that thrives in coconut debris. This proactive approach serves as an effective measure to prevent pest proliferation, as well as mitigating productivity losses and safeguarding farmers' incomes.

Social viability and inclusiveness

The project developed principles to ensure gender-equitable sourcing of senile coconut stands, including by enhancing the skills of both women and men in rural agricultural communities to foster active participation in the EWP value chain, promoting capacity building and professionalization in the forestry sector, and facilitating inclusive consultations to improve livelihoods and involve women of all ages in decision-making.

Lessons learnt and recommendations

Enabling conditions	Coconuts have been the focus of extensive global research initiatives. FAO and a previous ACIAR project have already investigated the potential use of coconut stems as sawn timber. The current project builds on earlier ACIAR-funded research, which demonstrated the technical feasibility of peeling senile coconut stems and manufacturing coconut-based EWPs. The necessary equipment for conducting processing research is already mostly established and operational in Fiji, and the country's veneer and plywood manufacturers are well-equipped to contribute to the research and rapidly implement its findings.
Challenges and lessons learnt	A review of the potential of coconut veneer-based EWP supply chains has confirmed strong potential with no significant barriers. Market testing suggests that immediate demand exists for coconut EWPs and preliminary financial analysis indicates that coconut EWPs can be manufactured profitably. While no significant challenges have been identified, commercialization is reliant heavily on adoption by the existing veneer and plywood industry, which is advancing but has been slower than expected.
Recommendations for scaling-up	The objective is to expand coconut veneer production to other Pacific Islands once the current research questions have been addressed. The outcomes of this research are intended to equip veneer processors in Pacific Island countries and Australia with the capability to integrate coconut and other non-traditional forest resources into their processing and manufacturing operations. The project envisions creating a pathway to impact by developing a manufacturing protocol for profitable EWP production from coconut and other small-dimension forest resources. Coupled with market development efforts, this initiative aims to generate demand for these underutilized resources, addressing an existing gap.
Acknowledgements	This case study was developed with the valuable contributions and support of Rob McGavin, Research Facility and Project Manager, Agri-Science Queensland, Department of Agriculture and Fisheries, Queensland, and Nora Devoe, Research Programme Manager, Forestry, Australian Centre for International Agricultural Research (ACIAR).

Case study 5. Taylors Run Family Farm, Australia

Core information

Partners	Taylors Run Family Farm
Location and context	Taylors Run Farm is located in the New England Tablelands region of New South Wales (NSW), Australia. The farm covers 750 ha, which is typical for grazing properties in the region. Situated at an altitude of 1 000 metres, it receives an annual rainfall of 710 mm.
Key details	Taylors Run is a sixth-generation sheep and cattle family farm that practises agroforestry. Between 1940 and 1980, the region faced severe environmental degradation, losing over 25 percent of its tree cover due to land development and the expansion of mechanized agriculture. By 1980, Taylors Run had only 5 percent tree cover, impacting significantly the farm's ecosystem and productivity. In response, over the past 45 years the Taylor family have restored tree cover to 23 percent and are working toward a goal of 30 percent by 2030.
Agroforestry system	**Typology: Silvopastoral** The farm operates a silvopastoral system that integrates livestock production with forestry. It supports a herd of 3 500 Merino sheep for wool production and 100 beef cattle, managed alongside radiata pine *(Pinus radiata)* plantations. The pine trees are semi-thinned and extensively pruned to ensure high-quality timber, with an average rotation age of 35 years.
Approach and activities	Since 1980, the Taylor family has taken a proactive approach to restoring their degraded landscape and integrating agroforestry as a core component of their farm operations. Their efforts have resulted in the planting of over 250 000 trees, transforming the farm's tree cover from 5 percent to 23 percent. These activities have rehabilitated the farm's ecosystem and also diversified and strengthened its economic base. Silviculture has become a distinct enterprise within the farm's operations. This includes a comprehensive approach to tree establishment and management, involving direct seeding, tree protection and careful planning to ensure long-term sustainability and productivity. These activities are integrated with the farm's livestock enterprises, forming a robust silvopastoral system. The family invested in an on-site sawmill to add value to their timber products. This allowed them to process low-value pulp logs, initially valued at AUD 0.5 per green metric tonne (GMT), into high-value square timber worth approximately AUD 600 per GMT. This value-adding activity has significantly enhanced the profitability of the silviculture enterprise while reducing reliance on external timber markets. The integration of agroforestry necessitated adjustments to pasture management practices. These changes have enabled the farm to maintain robust livestock operations while accommodating extensive tree plantings.

Wood production and wood-based value chains

Wood production context	New South Wales is a significant contributor to Australia's timber and wood production, with plantation forestry playing a vital role in meeting domestic and export demands. Radiata pine is the most widely planted softwood species in the state, valued for its versatility, fast growth and adaptability to a range of environments. It is commonly used for construction, furniture and pulp production. The sector faces challenges, however, including market fluctuations, sawmill closures and competition from imported wood products, but it remains a cornerstone of sustainable forestry practices and rural economies in the region.
Main wood production purpose	The primary aim of wood production at Taylors Run is to create high-value timber products while complementing the farm's grazing enterprises. Radiata pine plantations are managed for diverse outputs, including sawlogs for construction, peeler logs for veneer and plywood, and pallet-grade timber processed on-site in the farm's sawmill.

Wood production and wood-based value chains *(continued)*

Wood-based agroforestry value chains and production details

Between September 2022 and January 2023, Taylors Run harvested a total of 2 454 m^3 of logs, reflecting a diverse range of wood products. The harvest breakdown was as follows:

- pulp logs – 1 154 m^3 (47 percent of total volume),
- sawlog – 681 m^3 (28 percent of total volume),
- peeler logs – 469 m^3 (19 percent of total volume),
- high-performance poles (HPP) sort 2: 75 m^3 (3 percent of total volume),
- HPP sort 4: 75 m^3 (3 percent of total volume).

The logs were sold to Australian mills between Grafton, NSW (250 km northeast of the farm) and at Oberon, NSW (570 km southwest).

Outcomes

Economic viability and other socioeconomic benefits

Between September 2022 and January 2023, the total harvest generated AUD 55 527.89, averaging AUD 22.60 per m^3 across all log types. The breakdown of contributions highlights the economic importance of higher-value products:

- pulp logs – AUD 577 (1 percent of total value),
- sawlogs: AUD 23 837 (43 percent of total value),
- peeler Logs: AUD 25 824 (47 percent of total value),
- HPP sort 2 and sort 4: AUD 2 646 (5 percent) and AUD 2 643 (5 percent), respectively.

The farm's on-site sawmill adds significant value to lower-grade logs. For instance, a 4.5-m pulp-grade log with a 20 cm diameter, initially sold for AUD 0.08 per log, can be transformed into 100 × 100 mm square pallet-grade timber, yielding a profit of AUD 23 per log – an astounding 26 000 percent value increase.

With gross income per hectare ranging from AUD 150 to AUD 220 annually, these activities demonstrate how agroforestry can provide steady, diversified income streams. The ability to process and market high-value timber directly has been pivotal in offsetting the low returns of pulp logs and ensuring the financial viability of the silviculture enterprise.

Environmental co-benefits

By incorporating tree cover into grazing areas, the farm has improved microclimates for livestock, enhanced soil health and increased pasture productivity. However, the benefits extend far beyond the original aims of simply shade and shelter.

The farm has supported the regeneration of endangered woodland ecosystems and biodiversity restoration, and is now home to over 125 bird species. Natural regeneration processes have been re-established, contributing to a more balanced and resilient landscape.

The farm also sequesters over 600 tonnes of CO_2 annually, based on recent modelling. This carbon sequestration also helps rebuild stocks lost by previous generations.

Social viability and inclusiveness

Agroforestry at Taylors Run has fostered significant social benefits, strengthening connections within the family and the broader community. The restoration of the landscape has deepened the family's sense of place, reinforcing their commitment to stewarding the land for future generations.

The farm has also become a space for sharing knowledge and experiences, hosting farmer-to-farmer education and mentoring initiatives that inspire others to adopt sustainable practices. Additionally, the aesthetic and ecological appeal of the property has created opportunities for tourism, drawing visitors to learn from and appreciate the farm's agroforestry journey.

Lessons learnt and recommendations

Enabling conditions	The success of agroforestry at Taylors Run has been underpinned by a range of enabling factors, from land rights and financial resources to supportive education and regulatory frameworks. The family's long-term connection to the land, coupled with outright ownership, has been critical in fostering a commitment to tree planting and landscape restoration. This stability has allowed them to steward tree investments over decades without the pressure of immediate returns, and to plan for sustainable practices that align with their values. The family has also benefited from higher education in the forestry sector and ecology. Additionally, access to agricultural extension services, the latest technologies and regulated markets has provided a strong foundation for continuous improvement and adaptation. The ability to access capital through land equity and maintain profitability most years has allowed the family to invest in long-term agroforestry initiatives. Even in the face of declining timber market values and rising costs, they have sustained these efforts by adding value through an on-farm sawmill and balancing timber production with livestock enterprises. The flexibility to delay timber harvests when market conditions are unfavourable has further supported their financial resilience. Policies and regulations in Australia have not constrained the integration of agroforestry, while a general governmental emphasis on agriculture as a cornerstone of food and fibre security has provided an enabling environment. This context, combined with a competitive and transparent market structure, has driven innovation and efficiency in farm operations.
Challenges and lessons learnt	Access to markets remains a significant challenge for Taylors Run's agroforestry enterprise, particularly due to its remote location far from major urban centres like Sydney and Brisbane. The family aims to bypass wholesale channels and directly access local markets to maximize returns, yet this approach is constrained by the scale and infrastructure needed to reach local buyers effectively. Moreover, the timber market landscape can change dramatically over the decades it takes for trees to reach maturity, creating uncertainty for long-term planning. Market fluctuations and limited opportunities to sell lower-grade timber have underscored the importance of focusing on high-value forest products. Value-adding activities, such as processing timber on-site, can significantly enhance profitability and cover transport or access to markets costs.
Recommendations for scaling-up	The experience of Taylor's Run demonstrates that establishing agroforestry systems requires substantial upfront investment and expertise. Capital availability – whether through grants, subsidies or loans – is essential to support farmers in adopting agroforestry and achieving associated long-term benefits. Carbon and biodiversity market incentives alone are insufficient for most farmers. These mechanisms need to be complemented by robust financial and technical support systems to ensure agroforestry's widespread adoption and sustainability.
Acknowledgements	This case study was developed with the valuable contribution and support of Michael Taylor, farmer, Taylors Run Family Farm.

Case study 6. Takachihogo-Shiibayama mountainous agriculture and forestry system, Japan

Core information

Partners	GIAHS Takachihogo-Shiibayama Site Revitalization Committee
Location and context	Located in Miyazaki Prefecture in Kyushu region, Japan, the Takachihogo-Shiibayama site spans five villages in a steep, mountainous area surrounding by the Kyushu-Sanchi range, with elevations from 1 000 to 1 700 metres. The area has a temperate, humid climate and approximately 92 percent of the site is forested, with nearly half consisting of planted forests. Arable land makes up just 3 percent of the area, yet supports distinctive agricultural practices, notably terraced rice fields skilfully constructed on the steep slopes.
Key details	The Takachihogo-Shiibayama Mountainous Agriculture and Forestry System was designated as a Globally Important Agricultural Heritage System (GIAHS) in 2015, under the FAO programme established in 2002 to preserve and support traditional agricultural systems worldwide. The site earned this recognition for its integrated landscape management, which combines timber production with diverse agricultural practices such as shiitake mushroom cultivation, terraced rice farming, beef cattle raising and tea production. This composite system promotes sustainable forest use while generating significant income for local households. A key feature of this approach is the mosaic-pattern forest, characterized by a blend of conifers, deciduous broadleaf trees and evergreen species, maintained through the joint management of timber production and shiitake cultivation.
Agroforestry system	**Typology: Multiple (silvopastoral/shifting cultivation/woodlots)** The site features a composite agroforestry system at the landscape level: • Shifting cultivation is practised traditionally in Shiiba Village. Small plots of 0.5–1 ha are cultivated in cycles of buckwheat, millet and legumes, followed by 20–30 years of fallow for forest regeneration. • Mosaic forests consisting of conifers (e.g. Japanese cedar, Hinoki cypress), broadleaf trees (e.g. Sawtooth oak) and evergreen forests are managed jointly, creating patchwork landscapes. • Rice terraces are built on steep slopes and irrigated by extensive canal networks. • Shiitake mushroom cultivation is carried out primarily using Sawtooth oak logs. • Cattle rearing is largely small in scale and uses roughage from local vegetation.
Approach and activities	Agroforestry practices are implemented at multiple scales, from household-level farming to broader community-driven forestry management. The approach is participatory, emphasizing community organization and collaboration, particularly in Morotsuka Village, where initiatives such as FSC-certified forest management and shiitake mushroom value chains are developed.

Wood production and wood-based value chains

Wood production context	Japan's wood production sector is characterized by a mix of domestic forestry and imported timber, driven largely by the demand for construction, furniture and paper products. Major cultivated species include Japanese cedar *(sugi)*, Hinoki cypress *(hinoki)* and larch, which are commonly used for structural timber, joinery and wood panelling. Kyushu, one of Japan's leading forestry regions, contributes significantly to domestic timber production, particularly of conifers like Japanese cedar and Hinoki. Kyushu's timber industry also supports shiitake mushroom cultivation, utilizing hardwoods like Sawtooth oak. The GIAHS site is one of the key timber-producing areas of Miyazaki Prefecture, which ranks second nationwide for timber production.
Main wood production purpose	The wood produced is destined mainly for local use for shiitake mushroom cultivation and sale on national timber markets.

Wood production and wood-based value chains *(continued)*

Wood-based agroforestry value chains and production details	Morotsuka Village is a global pioneer in shiitake mushroom cultivation, relying on sustainably sourced raw wood, like Sawtooth oak and Japanese oak. It was the first village in Japan to receive FSC-C012945 forest certification and later earned FSC-C001800 sustainable forest management Chain of Custody (CoC) certification for its processing and distribution operations. Additionally, Morotsuka, in collaboration with the Mimi River Area Forest Cooperative and others, launched the Direct Shipment Housing initiative to better connect producers and consumers. By 2013, this initiative had supplied timber for 315 houses, actively engaging urban buyers in sustainable housing materials. The site produces approximately 230 000 m^3 of timber annually, mainly from Japanese cedar and Hinoki cypress, most of which is transported off-site as raw logs. Around 80 percent of the forests are privately owned and actively managed, about 58 percent of which are planted specifically for timber production.

Outcomes

Economic viability and other socioeconomic benefits	The composite system supports diversified incomes from timber, mushrooms, rice, tea and cattle. This diversification stabilizes household incomes, with gross revenues in the area shared between livestock (48 percent), forestry (25 percent) and shiitake mushrooms and other agricultural products, including rice, vegetables and tea (73 percent). Morotsuka Village produces about 370 tonnes of dried shiitake mushrooms annually – over half of Miyazaki Prefecture's total output. Miyazaki ranks second nationwide for dried shiitake production. Around 32 percent of the workforce in the site is employed in agriculture, a figure eight times higher than Japan's national average. Despite the small scale of cattle rearing, the region is also renowned for producing high-quality beef due to excellent management practices. Alongside cattle rearing and rice cultivation, a significant share of agricultural output also comes from the cultivation of vegetables, tea, fruit trees, flowers and ornamental plants.
Environmental co-benefits	The site's composite agriculture and forestry system supports habitats for rare species, including ten plants and animals listed in Miyazaki Prefecture's Red Book, such as the Japanese Cypripedium and *Calanthe Sieboldii*, even within managed cedar forests. Local biodiversity is maintained through careful forest management practices, including weeding, thinning and cleaning at optimal intervals, ensuring the conservation of these important habitats.
Social viability and inclusiveness	The site sustains livelihoods and also fosters valuable cultural traditions. Among these is kagura – ritual Shinto dances performed by entire villages to honour the gods of Japanese mythology believed to reside in the forest-covered mountains. These dances, which express gratitude for blessings and prayers for abundant harvests, are central to the community's cultural identity. The tradition of kagura also strengthens *yui*, the mutual cooperation system essential to maintaining village communities. The site's landscape is further enriched by landmarks, shrines and Buddha figures tied to local myths and folklore, as well as agricultural rituals like the Shishikake Festival and folk songs such as "Kariboshikiri Uta" and "Hietsuki Bushi".

Lessons learnt and recommendations

Enabling conditions	Despite the site's challenging mountainous terrain, both the public and private sectors have developed forestry infrastructure, including forest roads, and actively support forestry cooperatives. As a result, the area now boasts Japan's highest forest road density at 62 m/ha. In Morotsuka village, specifically, several initiatives have proven particularly helpful, notably: 1) a 1960 policy preventing land transfer to outsiders, thereby protecting forests from potential clear-cutting; 2) a shiitake raw wood-banking system to stabilize supply and demand; and 3) the creation of an autonomous Community Hall Committee for all village residents that drives education, infrastructure development and local productivity.

Lessons learnt and recommendations *(continued)*

Challenges and lessons learnt	Similar to other mountainous areas in Japan, the site has a declining and ageing farming and forestry workforce. Increased import liberalization has intensified competition, both domestically and internationally, raising concerns about the abandonment of farmlands and forest management due to insufficient income. Lessons learnt emphasize the need for greater investment in youth engagement, innovative financial mechanisms, and stronger marketing strategies to enhance the profitability and sustainability of these systems.
Recommendations for scaling-up	Being certified as a GIAHS site has helped instil a strong sense of pride among households that protect the forest, encouraging the continued maintenance of the site's sustainable agriculture and forestry system. It also plays a potentially crucial role in attracting and inspiring a new generation to step into agriculture and forestry, helping to address the challenge of an ageing workforce. Global recognition of the site's composite management system, particularly its mosaic forest that harmonizes forest conservation with production, provides a valuable model for other countries aiming to balance these sometimes conflicting aims. To enhance upscaling efforts, the site plans to collaborate with universities and research institutions on topics like sustainable agriculture-forestry integration, and to develop innovative business models, such as the growth of a senary (sixth-sector) industry that leverages forest resources and traditional culture. The insights gained will be shared globally to inspire similar initiatives.
Acknowledgements	This case study was developed with the valuable contributions and support of Tomonori Tasaki, GIAHS Coordinator, Takachihogo Town Office, Policy Management Department, and Akiko Inoguchi, Halting Deforestation and Climate Change Expert, FAO.

Case study 7. Binh Minh Agroforestry Cooperative, Viet Nam

Core information

Partners	• FAO Forest and Farm Facility (FFF) • Viet Nam Farmers' Union (VFNU)
Location and context	The Binh Minh Agroforestry Cooperative is located in Phu Thinh Commune, Yen Binh district of Yen Bai Province, a mountainous region of northern Viet Nam. Forestry and agriculture are the primary economic drivers of the province.
Key details	The Forest and Farm Facility (FFF), a partnership between FAO, the International Institute for Environment and Development (IIED), the International Union for Conservation of Nature (IUCN) and AgriCord, is a global programme that focuses on the strengthening of forest and farm producer organizations (FFPOs) as primary agents for climate resilience and improved livelihoods. In Viet Nam, the Viet Nam Farmers' Union (VFNU) is the main implementing partner of the FFF in four provinces of the country. The Binh Minh Agroforestry Cooperative (BMAC) was one of the first FFPOs to receive support from the FFF and VNFU. What began as a spontaneous group of acacia growers, who occasionally met and sold timber individually, has evolved into a registered cooperative with 18 member households, who own 60 ha of FSC-certified plantation forest.
Agroforestry system	**Typology: Woodlots/intercropping** The cooperative members cultivate primarily acacia in woodlots, producing FSC-certified timber. Many members also diversify their activities by integrating crops and fruit trees, and utilizing the understory for honeybee farming and poultry raising, both for household consumption and for sale.
Approach and activities	The Forest and Farm Facility and VNFU helped to formalize the cooperative structure, providing capacity development and helping them to achieve FSC certification. FFF conducted training on facilitation skills, market analysis and development, and organizational management for the group. It also provided small grants to facilitate successful FSC models, and offered technical training sessions on FSC requirements for cooperative members and other farmer groups in the commune. To strengthen partnerships, the FFF and VNFU facilitated roundtable discussions at the commune, district and provincial levels, connecting FFPOs with scientists, private sector stakeholders and decision-makers. These discussions also advocated for policies supportive of cooperatives and collective groups. Crucially, the FFF's support enabled the cooperative to establish connections with investors and markets, creating the economic incentives needed for members to commit to long-term engagement. Today, the Binh Minh Cooperative is a self-sustaining, economically viable enterprise and has recently opened a new sawmill. The FFF continues to engage with the cooperative, regularly monitoring and evaluating operations and addressing emerging challenges. The FFF organizes annual networking meetings that allows FFPOs in Viet Nam to share experiences and best practices.

Wood production and wood-based value chains

Wood production context	In 2020, Viet Nam was the leading exporter of wooden furniture in the Association of Southeast Asian Nations (ASEAN), second in Asia and fifth globally, with export values reaching USD 13.23 billion, up from USD 2.18 billion in 2006 (ITTO 2021). However, domestic timber production remained low at 20.5 million m^3, despite having 3.7 million ha of production forest. The Viet Nam Forestry Development Strategy 2006–2020 aimed for 30 percent of production forests to achieve sustainable forest management certification, but only 3.3 percent met this target (Trieu, Pham and Đào Thị, 2020). Additionally, only 20 percent of domestic timber was suitable for the furniture sector, with the remainder used for woodchip processing. The country's ability to meet targets has been hindered by fragmented timber supply chains, with 1.4 million households managing 3.15 million ha of forest and supplying 4 500 processing companies.

Wood production and wood-based value chains *(continued)*

Main wood production purpose	The main products are acacia and FSC-certified acacia sawn logs. Among the principal customers is Hoa Phat, one of the largest timber-processing companies in northern Viet Nam and an IKEA supplier. Branches and treetops are also transformed into charcoal and pellets.
Wood-based agroforestry value chains and production details	The value chain for timber produced by the cooperative ranges from planting and harvesting acacia to processing the timber into sawnlogs at the cooperative's sawmill. The sawnlogs are then sold to companies like NAFOCO and Hoa Phat, which supply large furniture manufacturers. The cooperative has forged affiliations with more than 2 000 households involved in forest planting, covering an extensive 650-ha expanse across 24 communes and towns in Yen Binh district. The cooperative's sawmill processes approximately 1 000 m^3 of timber each month.

Outcomes

Economic viability and other socioeconomic benefits	Thanks to FSC certification, members receive a premium price for their timber, which can be 10–15 percent higher than that for non-certified timber. Over a five-year period (2018–2022), the cooperative generated revenues of VND 6 billion, averaging VND 1.2 billion (USD 53 000) in net profit per year and creating 15 full time jobs for local people, who received daily wages of VND 230 000–270 000 (USD 10–12), enhancing local employment and increasing incomes (Nguyen, 2023). In line with FSC-CoC requirements, the cooperative prioritizes labour safety by providing personal protective equipment to all workers. The cooperative has also improved farmer bargaining power and reduced reliance on intermediary buyers.
Environmental co-benefits	In adhering to FSC standards, the cooperative ensures that its timber production practices are environmentally sustainable. This includes minimizing the use of herbicides, preventing soil erosion and enhancing biodiversity through better forest management practices. These efforts have led to improvements in the health of local ecosystems, including better soil quality and the restoration of degraded lands.
Social viability and inclusiveness	The cooperative has built a robust collective organization that fosters trust and solidarity among its members. By supporting one another, members develop stronger relationships and a sense of unity, enabling them to tackle challenges effectively. This solidarity promotes a shared identity, resilience and commitment to the cooperative's mission.

Lessons learnt and recommendations

Enabling conditions	Several key factors have contributed to the cooperative's success over time, including strong leadership, member solidarity, capital availability, the involvement of large companies, stable growth in the wood products market, and support from government initiatives and donor projects. A key aspect of this success has been strong multistakeholder collaboration. The involvement of government, the private sector, the VFNU and FFF has provided technical expertise, improved value chains, expanded market access and contributed to investments. Accordingly, this case demonstrates how external actors play essential roles in offering market incentives, policy support and capacity building, all of which help to sustain FFPOs.
Challenges and lessons learnt	Although the cooperative has a proven track record, it still faces challenges, including land tenure insecurity. Members can only rent land for five years, and not all of them possess land use certificates. This uncertainty makes shareholders hesitant to invest further and restricts access to bank loans. Furthermore, the high proportion of households without land use certificates in the district impedes FSC upscaling due to increased conflict risks. While the Binh Minh Cooperative benefits from strong collective organization, disparities in benefits between dividend-earning and non-dividend-earning members affect engagement and decision-making. Since the cooperative provides job opportunities and services to the entire community, there is often little distinction in benefits between non-dividend members and non-members, resulting in lower interest and influence in cooperative decisions among those who do not receive dividends.

Lessons learnt and recommendations *(continued)*

Recommendations for scaling-up	Continued policy support and financial mechanisms that incentivize long-rotation forestry are crucial for the cooperative's long-term success. The most successful business models have emerged from a combination of strong internal governance, clear market incentives, supportive policies and private sector involvement, including investments and financing, and adequate external resources that allow for sufficient incubation time.
Acknowledgements	This case study was developed with the valuable contributions and support of Pham Thang, National Programme Coordinator, Forest and Farm Facility, FAO Viet Nam, and Sophie Grouwels, Global Coordinator, Forest and Farm Facility, FAO.

Case study 8. Smallholder teak agroforestry systems in Gunungkidul, Indonesia

Core information

Partners	Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF)
Location and context	Gunungkidul, located in the Special Region of Yogyakarta, is characterized by a hilly landscape, with elevations ranging from 0 to 800 metres above sea level, and an average annual rainfall of 1 500–2 500 millimetres.
Key details	Gunungkidul is renowned for its extensive history of smallholder teak production, integrated with other timber and tree species. Virtually every farming household incorporates teak cultivation into their livelihood strategies, making it a cornerstone of the local economy. Yogyakarta, Central Java and East Java are considered the heart of Indonesia's teak industry, with Gunungkidul standing out as a key contributor. In the 1950s, Gunungkidul faced severe environmental degradation due to the expansion of unsustainable agriculture practices onto marginal lands to support a growing population. Deforestation and soil erosion were widespread, threatening both livelihoods and the ecological balance. Over the past six decades, however, smallholder farmers have adopted agroforestry practices, transforming the landscape. The establishment of tree-based agricultural systems has played a crucial role in rehabilitating degraded land and promoting sustainable natural resource management in the region (Sabastian *et al*., 2014).
Agroforestry system	**Typology: Multiple (Homegardens/woodlots/boundary planting)** Smallholder farmers in Gunungkidul integrate teak cultivation into four commonly practised agroforestry systems: • **Kitren** are woodlots predominantly composed of teak, often located 1–1.5 km from farmers' homes. • **Tegalan** refers to upland intercropping systems, where teak is intercropped with annual crops such as cassava, peanuts and upland rice, often located 1–1.5 km from farmers' homes. • **Pekarangan** are home gardens located adjacent to farmers' homes, dominated by tree species, including teak, with crops in the understory. • **Line plantings** consist of teak planted along the border of irrigated rice fields or other cropping systems.
Approach and activities	Since 2007, CIFOR-ICRAF, research agencies under the Ministry of Forestry and district governments, and private sector partners have collaborated on research initiatives in Gunungkidul to improve smallholder teak systems, enhancing timber and NWFP production, marketing and sustainable livelihoods. The growth and prominence of smallholder agroforestry systems in the region are the result of a combination of spontaneous tree planting by farmers, the government's *penghijauan* (reforestation) programme, and collaborative research and development initiatives led by the aforementioned stakeholders. Families own an average of 1 ha of land, typically divided into parcels, with 30–50 percent of land incorporating teak as a key component. Farmers have innovatively used teak, alongside other species, as a productive fallow crop to restore degraded agricultural land (Sabastian *et al*., 2014). Across all four types of primary systems, teak accounts for 56 percent of trees, with additional contributions from other timber species (21 percent), fodder species (15 percent), and a small proportion of fruit, spice and nut trees. Intercropping is widespread, practised by 82 percent of farmers, with common crops including rice *(Oryza sativa)*, cassava *(Manihot utilissima)*, peanuts *(Arachis hypogaea)*, soybeans *(Glycine max)*, corn *(Zea mays)*, bananas (*Musa* spp.) and other vegetables. Teak is typically harvested between 15 and 50 years of age, although younger trees may be cut to meet immediate household needs. Harvesting is usually done selectively and in small numbers, creating canopy openings that influence the system's ecological and agricultural dynamics. System transitions occur based on factors such as soil fertility, soil moisture, labour availability and livelihood needs. For example, *kitren* (woodlots) may transition to *tegalan* (intercropping systems) or border planting if soil improves. *Pekarangan* (home gardens) typically develop near homes when new households are established but rarely originate from *kitren* systems due to their timber focus.

Wood production and wood-based value chains

Wood production context	Indonesia is the second-largest producer of teak globally, following India. Industrial demand for teak timber in Central Java is estimated at 1.5–2.2 million cubic metres annually. Over the years, smallholder teak production has become a critical source of raw material for the Javanese furniture industry and a vital income stream for rural families. While demand for teak remains high, both nationally and internationally, smallholders face challenges in producing high-quality timber that meets export standards. Intensive silvicultural management is often required to achieve the desired quality, yet many smallholders lack access to the necessary knowledge, skills and market incentives. Despite these challenges, smallholder teak cultivation continues to play an essential role in sustaining Indonesia's teak industry and meeting growing global demand (Roshetko *et al*., 2013).
Main wood production purpose	The sale of standing trees is standard practice for farm-grown teak. Traders handle the harvesting and transport of timber, visiting farms to measure and assess the trees before negotiating prices.
Wood-based agroforestry value chains and production details	The smallholder teak timber marketing chain involves farmer producers, local traders, large-scale traders (wholesalers) and processors. Farmers operate primarily as producers, with limited roles beyond cultivation. They interact with the marketing chain through local or large-scale traders, but their access to market information is restricted, hindering their ability to negotiate favourable terms. Smallholder teak traders play a crucial role in linking supply and demand by performing sorting functions and streamlining distribution processes. Recent studies have shown that smallholders supply approximately 80 percent of the teak used by small- to medium-scale producers, primarily in the form of small-diameter logs (less than 30 cm in diameter). These producers, in turn, account for more than 90 percent of furniture-making at Jepara in Central Java (Roshetko *et al*., 2013).

Outcomes

Economic viability and other socioeconomic benefits	Teak cultivation diversifies income streams and serves as a financial safety net for households. Agroforestry systems provide approximately 40 percent of overall household income – 25 percent from agricultural production, 12 percent from teak and 3 percent from other timber species. Beyond timber, teak contributes additional economic value through the collection and production of germplasm, such as seeds and seedlings (Roshetko *et al*., 2013). Teak trees are regarded as "living savings accounts", harvested only when substantial cash needs arise, such as for weddings, school fees or medical emergencies. Households often prioritize selling other assets like motorcycles, electronic goods, jewellery or livestock before resorting to harvesting their teak – a practice locally termed *tebang butuh* ("felling for needs"). This strategy underscores teak's role as a crucial form of capital accumulation, allowing families to manage financial risks effectively. Moreover, by enabling households to reallocate labour to off-farm employment opportunities during favourable economic conditions, teak systems further enhance livelihood flexibility and stability.
Environmental co-benefits	The adoption of agroforestry systems for teak cultivation has played a key role in reversing environmental challenges, such as deforestation, soil erosion and declining agricultural productivity in the region, contributing to the restoration of degraded landscapes. Teak-based agroforestry systems have improved soil health by reducing erosion and increasing organic matter through leaf litter and root systems. Furthermore, the integration of teak with other tree species and crops has enhanced biodiversity, creating more resilient and productive farming systems. These systems have contributed to the overall reforestation of Gunungkidul, which was nearly treeless in the 1950s. Today, smallholder agroforestry accounts for 19.2 percent of the district's total tree cover, complementing the 8.9 percent from state forest lands (Roshetko *et al*., 2013).

Outcomes *(continued)*

Social viability and inclusiveness	Teak cultivation is deeply rooted in the community's cultural identity and traditions. These practices have evolved through decades of experience, careful observation, and a process of trial and error. For many farming households, planting teak is not only a practical activity but also a symbol of heritage and pride. A study by CIFOR-ICRAF found that a significant portion of farmers (23 percent) plant teak primarily because it is a part of their cultural heritage (Sabastian *et al*., 2014). Teak cultivation strengthens social cohesion within rural communities. This widespread tradition creates shared experiences, knowledge and practices among neighbours. While only 9 percent of farmers reported planting teak based on the influence or success of their neighbours, the collective presence of teak in farming systems underscores its role in uniting the community through common goals and practices.

Lessons learnt and recommendations

Enabling conditions	Agroforestry has been actively promoted in Indonesia for over 30 years as a cost-effective and sustainable land use system. The national government's rehabilitation and re-greening programmes, initiated in the 1980s, played a pivotal role in encouraging farmers to adopt tree-farming systems. These programmes provided initial investments in germplasm and technical support, strengthening farmers' interest in cultivating teak and other tree crops. The financial barriers to planting teak have been relatively low for smallholders. Most farmers have relied on locally available germplasm, such as wildlings, seedlings or coppice, reducing the need for significant cash outlays. The availability of government-supported planting materials further lowered costs, making teak cultivation accessible to resource-limited households. Teak cultivation aligns with the needs of smallholder farmers. Its flexibility as a low-input system allowing them to integrate teak into existing agroforestry practices without disrupting their primary agricultural activities. The long growth cycle of teak also enables them to prioritize annual crops while maintaining teak as a long-term asset.
Challenges and lessons learnt	Farmers are often reluctant to thin their teak stands, viewing thinning as a loss of future income. This results in dense plantings that limit understory space and reduce overall tree quality. When thinning is conducted, it frequently targets the best-quality trees, diminishing the potential of the remaining stands. Pruning, while practised for fuelwood collection, is not optimized to improve timber quality. Farmers' hesitation to thin teak systems could be addressed by integrating short-rotation species, which would provide early financial returns and reduce reluctance to thin. Farmers also lack adequate access to market information and rely on informal networks, such as other farmers or acquaintances, to determine prices. This limits their negotiating power. Smallholders typically produce small volumes of variable-quality timber, leading to lower prices and weak bargaining position in the market. Collective marketing groups and centralized market information systems could empower smallholders to secure better prices by increasing transaction efficiency and transparency. Capacity-building efforts focused on sustainable silvicultural practices, such as proper thinning and pruning, could improve timber quality and yield.
Recommendations for scaling-up	Introducing smallholders to log grading and pricing systems used by the timber industry could significantly improve their market awareness and negotiation power. Training sessions led by industry experts can equip both farmers and local traders with a deeper understanding of market standards and dynamics. Such initiatives pave the way for farmer-industry partnerships, enabling smallholders to align their production with specific market demands and produce timber of a consistent quality. Additionally, implementing a valuation system for standing trees on farms would enhance price transparency, mitigating risks for both farmers and traders. Clearer and more reliable pricing mechanisms can build trust across the value chain, encouraging smallholders to invest in improved silvicultural practices and produce higher-quality timber, ultimately benefiting both livelihoods and the industry.
Acknowledgements	This case study was developed with the valuable contributions and support of James Roshetko, Agroforestry System Scientist, CIFOR-ICRAF Indonesia, and Aulia Perdana, Agroforestry and Market Systems Consultant, Bogor.

Case study 9. Burapha Agroforestry, Lao PDR

Core information

Partners	Burapha Agroforestry Co. Ltd.
Location and context	Burapha operates in Vientiane Prefecture and the Provinces of Vientiane and Xayabouly of the Lao People's Democratic Republic (PDR). The area is characterized by slightly hilly, degraded forestland that has undergone shifting cultivation practices for centuries.
Project details	Burapha is a plantation timber and wood-processing company that manages timber plantations through an agroforestry model. It was founded in 1993 through a joint Swedish-Lao venture. Today it manages 9 622 ha of land of which 6 200 ha is planted.
Agroforestry system	**Typology: Woodlots/alley cropping/sequential** The Burapha timber plantations are composed primarily of eucalyptus, with some areas also planted with teak and acacia. During the first one to two years of the seven-year plantation cycle, trees are intercropped with upland rice and other crops. From the third to seventh year, as the canopy cover becomes denser and restricts crop production, grazing activities take place under the trees. This seven-year cycle is then repeated until the end of the lease agreement. In addition to timber production, the plantations are used for collecting NWFPs, with villagers also permitted to use the wood debris left after harvesting.
Approach and activities	Before 2020, the Burapha model involved leasing degraded forest lands from communities and individual landowners for agroforestry operations. In return, the company provided lease payments, seasonal employment, land preparation for intercropping between trees, and support for village infrastructure development, such as roads and bridges. In 2020, Burapha was granted a government concession for 2 000 ha within the production forest area (PFA). In 2022, this was expanded to include the right to survey and identify suitable land up to 60 000 ha of PFA, in agreement with farmers and the government. Since then, the company has focused on establishing new plantations exclusively within the PFA. To date, over 2 200 ha have been planted.

Wood production and wood-based value chains

Wood production context	The wood-processing industry of Laos PDR, which currently sources only about half of its wood domestically, relies heavily on timber plantations that supply approximately 90 percent of the country's roundwood, with eucalyptus and teak as key species for commercial production. Recognizing the potential to increase export value, the country is working towards sustainable growth by strengthening the legal, regulatory and institutional frameworks of its forestry and wood sectors.
Main wood production purpose	Burapha's wood products, including plywood, veneer and furniture, are sold on both local and international markets. The company's aim was to develop a large-scale timber plantation asset in Laos PDR to serve as the primary wood supplier for major industrial operations.
Wood-based agroforestry value chains and production details	The company has a vertically integrated value chain, operating a tree nursey, a veneer and plywood manufacturing mill, and a sawmill and furniture factory. It also has its own research and development programme. The plywood mill and sawmill/furniture factory both have FSC CoC certification. In 2022, Burapha produced 8 444 m^3 of plywood and 1 597 m^3 of teak and eucalyptus furniture.

Outcomes

Economic viability and other socioeconomic benefits	Up to the end of 2023, Burapha employed 500 staff. However, due to challenges in securing sufficient new funding, the company's operations have been suspended. Efforts are ongoing to attract new investors to revive operations. Currently, Burapha employs 60 full-time staff. In 2022, the company contributed USD 1.3 million to local communities through wages, Village Development Funds and infrastructure projects, including the construction and improvement of roads.
Environmental co-benefits	Burapha's agroforestry model supports the restoration of degraded land, as plantations are established on degraded vegetative landscapes, often used previously for swidden agriculture. These plantations are located primarily in foothill areas, deliberately avoiding sensitive habitats, productive floodplain land and native forests in mountainous regions. The model supports the creation of biodiversity corridors, the protection of waterways and improved soil health through intercropping practices. Additionally, 1 381 ha within or adjacent to the plantations are designated for conservation. The company has also completed its first validation and verification of carbon sequestration calculations and has applied for credits generated since 2016.
Social viability and inclusiveness	Burapha follows a "bottom-up" approach to land leasing, proactively reaching out to communities and individual landowners with proposals to lease land for agroforestry operations. Throughout the land identification and leasing process, Burapha engages with communities through Free, Prior and Informed Consent (FPIC), ensuring transparent and inclusive decision-making.

Lessons learnt and recommendations

Enabling conditions	Burapha's model aligns with government policies that aim to reduced reliance on swidden agriculture and the subsistence economy, as well as increase forest management and production in degraded land areas. In 2022, the government granted Burapha a concession to survey up to 60 000 ha and to retain areas for conservation within the Production Forest Area, in alignment with broader national goals. Financial mechanisms and compliance with international standards, such as the FSC and the International Finance Corporation (IFC), have further supported the company's expansion and credibility. It holds FSC certification for its entire landholding. Other enabling factors for the company's operations include a business structure led by experienced foresters, access to fast-growing plantation species, and a strategic plan for expanding plantation assets to support large-scale processing facilities, such as an existing sawmill and a plywood mill opened in mid-2021.
Challenges and lessons learnt	Burapha faces significant issues with illegal encroachment. Individuals establish unauthorized cassava and rubber plantations within the PFA area, and the company is unable to secure sufficient land for further plantation development. This unresolved issue has made potential investors cautious, perceiving Burapha as a high-risk investment.
Recommendations for scaling-up	Burapha plans to scale up its operations by expanding plywood mill production and progressively increasing its planted area to 10 000 ha within the next five to seven years. However, achieving this goal depends on securing reliable land tenure to support plantation expansion.
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Annexes

Annex 1. Definitions

Agroforestry systems (AFS) are land management systems that encompass the deliberate integration of trees, crops and/or livestock within a single management unit. When properly designed and actively managed, AFS are sustainable, productive and resilient systems that provide economic, social and environmental benefits to farmers, communities and society. These benefits accrue because well-adapted AFS utilize tree and crop species with complementary growth traits, chosen for their mutually beneficial interactions and which optimize the use of available natural resources, such as light, water and nutrients (FAO, 2023b).

Community-based forestry (CBF) includes "initiatives, sciences, policies, institutions and processes that are intended to increase the role of local people in governing and managing forest resources". It encompasses formalized customary and Indigenous initiatives as well as government-led initiatives. CBF covers social, economic and conservation dimensions in a range of activities including decentralized and devolved forest management, smallholder forestry schemes, community-company partnerships, small-scale forest-based enterprises and Indigenous management of sacred sites of cultural importance (Gilmour, 2016).

Ecosystem restoration refers to a wide continuum of practices that help conserve and repair damaged ecosystems, including the replenishment of organic carbon in agricultural soils and the restoration of biodiversity to states similar to those that existed prior to degradation.

Family farming is an undertaking that includes all family-based agricultural activities that are "a means of organizing agricultural, forestry, fisheries, pastoral and aquaculture production which is managed and operated by a family and predominantly reliant on family labour, including both women's and men's. The family and the farm are linked, co-evolve and combine economic, environmental, social and cultural functions" (FAO, 2018).

Forest and landscape restoration (FLR) is a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded [forested] landscapes.

Non-wood forest products is a term that refers to goods of biological origin other than wood derived from forests, other wooded land and trees outside forests (FAO, 2024).

Non-timber forest products is a term that refers to all NWFPs plus certain woody materials such as woodfuel and small woods (FAO, 2024).

Plantation forest is planted forest that is intensively managed and meets all the following criteria at planting and stand maturity: one or two species, even age class and regular spacing. Plantation forests are established for the production of timber, fibre, energy and non-wood forest products. Plantation forests composed mainly of introduced species represent a subcategory of plantation forests (FAO, 2020b).

Planted forest is forest composed predominantly of trees established through planting and/or deliberate seeding (FAO, 2020b).

Reforestation refers to the re-establishment of forest through planting and/or deliberate seeding on land classified as forest. It implies no change of land use, and includes planting/seeding of temporarily unstocked forest areas as well as planting/seeding of areas with forest cover. Reforestation incorporates coppice from trees that were originally planted or seeded, but excludes the natural regeneration of forest (FAO, 2020b).

Smallholders comprise small-scale farmers, pastoralists, forest keepers and fishers who manage areas varying from less than 1 ha to 10 ha. Smallholders are characterized by family-focused motives such as favouring the stability of the farm household system, using mainly family labour for production and using part of the produce for family consumption. The notion of smallholding is however context specific, and in forestry, smallholders have been considered as owning less than 100 ha but more than 0.5 ha (Evans, 2009).

Smallholder tree-farming systems include small-scale plantings of generally around 2 ha and often less than 0.5 ha in Southeast Asia. They may be integrated within ancillary land uses such as agroforestry, food crops and animal husbandry, and are often referred to as "trees outside forests" (FAO 2010; Flanagan *et al*., 2019).

Social forestry is used as an overarching term referring to the management of forests by and for local communities, Indigenous Peoples and ethnic minorities. It includes various forms of community forest management, such as community forestry, community-based forest management, community protected area management and village forestry (ASEAN, 2022).

Trees outside forests are trees growing on land not categorized as forest (e.g. other wooded land and other land with tree cover) (FAO, 2022b).

Annex 2. Wood products and services provided by smallholder systems

A2.1 Wood products

Wood fuel

In the last 35 years, growth in traditional woodfuel usage – as firewood and charcoal – has remained stable or declined in many regions of the world, but has increased in Southern Asia (FAO, 2022a), including in India where woodfuel accounts for 18 percent of total energy consumption (Bhattacharya, 2015). In many rural areas, fast-growing tree species like acacia and eucalypt are harvested for firewood – an essential energy source for households. This process uses thinning to support local energy needs while meeting stem density regulations in agroforestry systems (van Noordwijk, 2019).

Biofuel and biomass

Demand for wood-based bioenergy in the renewable energy mix is expected to rise by 2050 (FAO, 2022a). Bioenergy pathways are able to utilize forest residues and wood waste, thereby adding value to woody biomass that might otherwise be underutilized (Brady *et al*., 2023). Additionally, species such as *Pongamia pinnata* and *Calophyllum inophyllum* produce oils that can be processed into biofuel, providing a renewable energy source (Keenan, 2019).

Pulp and paper

Smallholder wood production frequently focuses on pulp and paper. This is the case with eucalypt plantations in Thailand, or *A. mearnsii* in China, which is valued for its tannin-rich bark and wood suited for pulp production. However, with the decline in plantation areas, commercial wood production from acacias has diminished and shifted towards eucalypts, producing veneer logs as a higher-value product (Arnold *et al*., 2020). Residues from veneer production continue to be used for pulp and woodchips, ensuring maximum utilization of the harvested trees (Arnold *et al*., 2013).

Wood chips

Wood chips are of increasing importance in smallholder wood production in the Asia and the Pacific region. Smallholder farmers in Viet Nam grow acacia species on short rotation primarily for the hardwood export market, especially to China and Japan, which makes the country the largest exporter of hardwood chips globally (Carias *et al*., 2022; Keenan, 2019).

Sawn timber and furniture

Despite a lack of consolidated statistics at the regional level, the importance of timber as a harvested wood product is recognized for many smallholder tree-farming systems across Asia and the Pacific. High-quality timber from teak, eucalyptus, acacia and other species is used in construction, furniture-making and other industries, providing a valuable source of income for smallholder farmers (van Noordwijk, 2019).
For example, in Thailand, smallholder teak and rubberwood are widely used in the manufacture of furniture, while teak is also used for panelling. In Papua New Guinea, ongoing efforts to improve teak germplasm aim to enhance the quality and productivity of teak timber and improve economic returns for smallholders (see Case study 3).

Veneer, plywood and panels

Smallholder tree-farming systems in countries with advanced wood-processing industries, such as China and Indonesia, also supply wood for processed products, including veneer, wood-based panels and pulp (FAO, 2019). Meanwhile, Fiji is a pioneer in the innovative use of wood-processing technologies to transform senile coconut stems into high-quality veneer (see Case study 4).

Poles and posts

Trees grown in agroforestry systems also provide poles and posts used in local construction, fencing and agricultural support structures (van Noordwijk, 2019).

A2.2 Non-wood forest products

Smallholder wood production systems provide a wide range of NWFPs across the region. These include food products, such as nuts, mushrooms and fruits, medicinal and aromatic plants, essential oils, resins and gums, fibres, dyes, fodder and others. Notably, the leaves of eucalypts, particularly *E. globulus*, *E. maidenii* and *E. smithii,* are frequently harvested for essential oils (Arnold *et al*., 2020). In Indonesia, *C. inophyllum* and *P. pinnata* provide these and other valuable products, including fodder, and organic matter for composting or honey production (Baral, Leksono and Seol, 2022). In Bhutan, East Indian Lemon Grass is harvested and distilled in community forests to make lemon grass essential oil (Darabant *et al*., 2016). Meanwhile, the Takachihogo-Shiibayama Site in Japan combines timber production with high-value shiitake mushroom cultivation, utilizing Sawtooth oak logs (see Case study 6).

A2.3 Crops

Subsistence crops

In many parts of Asia and the Pacific, agroforestry systems intercrop tree species with annual crops like rice, maize, root crops (Maharani *et al*., 2022) and vegetables. This practice allows farmers to continue crop production while the trees mature, thereby diversifying their income sources (van Noordwijk, 2019).
In Lao PDR, eucalypts are intercropped with rice or cassava during the first year of a seven-year rotation (Phimmavong *et al*., 2019), a model exemplified by Burapha Agroforestry (see Case study 9). In Indonesia, agroforestry systems using bioenergy tree species are integrated with crops like rice, maize and peanuts, supporting food production.

Cash/high-value commodities

Trees are also grown alongside shade-tolerant cash crops, such as coffee and cocoa, especially in Indonesia and Viet Nam. The shade provided by tree species like teak and acacia benefits these crops, enhancing both agricultural productivity and income (van Noordwijk, 2019). In Indonesia and the Philippines, cacao *(Theobroma cacao)* is a crucial agroforestry species for fruit production, while in Indonesia, *Coffea arabica* (Coffee) is integrated into agroforestry systems for its commercial fruit value (Ashton *et al*., 2023).

A2.4 Ecosystem services

Biodiversity conservation

Integrated systems, such as those employing mixed-species agroforestry with various tree species, fruit crops and understory vegetation, create a complex mosaic of ecological niches and habitats (van Noordwijk, 2019). The resulting increase in biodiversity enhances the provision of ecosystem services, including agricultural productivity (Carias *et al*., 2022; FAO, 2019).

Soil and water conservation, climate regulation and land restoration

Agroforestry systems, particularly those that integrate nitrogen-fixing species, like acacias and Pongamia, have proven highly beneficial in restoring degraded lands, due to their effectiveness in enhancing soil fertility, stabilizing soil and regulating water cycles (Baral, Leksono and Seol, 2022; FAO, 2019). Leaf litter from trees further enriches soil organic matter, boosting productivity (van Noordwijk, 2019). However, eucalypts, which are very common in smallholder wood production systems across the region, require careful management due to their high water consumption, which can strain local resources in water-scarce areas (Arnold *et al*., 2013). Management practices in small-scale wood production systems, therefore, need to pay attention to the risks of soil erosion following clearcutting, which is likely to be amplified by increasing climate change impacts (Schröder *et al*., 2024).

Carbon sequestration

Despite their small individual size, smallholder tree-farming systems, widespread across the region, play a vital role in carbon sequestration by capturing and storing carbon in tree biomass and soils (Baral, Leksono and Seol, 2022; FAO, 2019). For instance, Taylors Run Farm in Australia, which incorporates tree cover into its grazing areas, now sequesters over 600 tonnes of CO_2 annually, based on recent modelling (see Case study 5).

Annex 3. Common species in smallholder tree-farming systems

Eucalypts

Several fast-growing species and hybrids of eucalypts are cultivated extensively by smallholders across Southeast Asia, China and India. Valued for their rapid growth, adaptability to diverse environments and versatile applications, they function as a cornerstone of regional wood production (van Noordwijk, 2019). Eucalypts dominate smallholder wood production in China, and are also integral to plantations in Lao PDR and Viet Nam. In Viet Nam, in particular, they have been cultivated for decades in farm forestry, both in short and long rotations to meet diverse market demands, including for pulp, timber and energy products (Keenan, 2019). In Thailand, eucalypts are the second-most preferred species for smallholders, and are used predominantly in the pulp and paper industry.

Acacias

Across Asia and the Pacific, acacia species such as *Acacia mangium* and *A. auriculiformis*, as well as hybrids, are commonly incorporated into agroforestry systems due to their effectiveness in fixing nitrogen, resulting in benefits for agriculture, and their versatility in producing timber, firewood and pulpwood (van Noordwijk, 2019). Acacias are also important smallholder plantation species for wood production in Lao PDR, Thailand and Viet Nam, and are widely cultivated in the latter country both in short rotations (primarily for woodchips) and long rotations (furniture-grade timber) (Le *et al*., 2022).

Teak

Teak *(Tectona grandis)* plays a significant role in agroforestry systems for high-value timber production, mainly in Southeast Asia, India, Indonesia, the Philippines and Sri Lanka (Ashton *et al*., 2023). Teak is one of the few valuable hardwood species globally that is widely grown in plantations; however, it suffers from a narrow genetic base of planting stock (Kollert and Kleine, 2017). Smallholders often integrate teak into their farming systems due to its market value and ability to thrive under diverse conditions (van Noordwijk, 2019). For example, in Thailand, teak is considered the most valuable plantation species, grown in 30-year rotations and used for furniture and types of interior decoration.

Poplar

Poplar species, particularly *Populus deltoides*, *P. nigra* and their hybrids, are a vital component of smallholder wood production systems across the region, especially in China, India and Pakistan. Known for their fast growth, adaptability to diverse climatic conditions and compatibility with intercropping, poplars support both industrial demand and smallholder incomes. In China, smallholder poplar plantations are utilized by the plywood and veneer industries, often in combination with eucalypts (Arnold *et al*., 2013).

Rubber

Rubber *(Hevea brasiliensis)* plantations have also been identified as significant contributors to wood supply. When rubber trees reach the end of their productive life for latex production, they are harvested for timber, which is increasingly used in the plywood, veneer and furniture industries (FAO, 2022a). The most common species in Thai smallholder plantations is rubber, grown on 30-year rotations and used for furniture.

Other trees of regional importance for wood production

Mahogany *(Swietenia macrophylla)* is a valuable timber species planted in India and Indonesia for its high-quality wood (Ashton *et al*., 2023). Casuarinas are common in farm forestry systems in Viet Nam, where they have been cultivated for decades and are easy to propagate, tend and harvest. *Pongamia pinnata* is a multi-purpose species found in South and Southeast Asia optimal for restoring degraded landscapes using agroforestry (Baral, Leksono and Seol, 2022).

Trees primarily grown for fruits or other products

Indigenous tree species are often included in agroforestry systems. They provide food (e.g. fruits and nuts), medicines and a range of NWFPs for subsistence consumption and sale (FAO, 2019). These trees not only provide wood but also offer additional income streams, especially in South and Southeast Asia (van Noordwijk, 2019) (see Box 4).

Box 4 Examples of trees primarily grown for fruits or other products in Asia and the Pacific

Mango *(Mangifera indica)* is grown for fruit production in agroforestry systems, particularly in India and several Southeast Asian countries (Ashton *et al*., 2023). Moringa *(Moringa oleifera)* is a multipurpose tree, cultivated for food and vegetables in India and Nepal, that integrates well into smallholder systems (Ashton *et al*., 2023). Nyamplung *(Calophyllum inophyllum)* is suitable for land restoration in agroforestry systems and provides wood, non-edible oil that can be used for biofuel, medicine, cosmetics and animal feed, and compost for soil enrichment (Baral, Leksono and Seol, 2022). Sengon *(Falcataria falcata)* is a fast-growing species widely grown by smallholders as part of an agroforestry system in Pati, Central Java, Indonesia, and is often integrated with understorey crops such as rice and cassava. Whitewood *(Endospermum medullosum)* is native to Espiritu Santo Island, Vanuatu, designated as a priority species for plantation development, where smallholder plots are generally less than 1 ha in size (Carias *et al*., 2022). Yang Bong *(Persea kurzii)* is grown in agroforestry systems with bananas in Lao PDR, providing both wood and NWFPs. and thus multiple income streams for smallholder farmers (Keenan, 2019).

Bamboo

Bamboo is known for its rapid growth and suitability for degraded land. Beyond its potential to substitute for wood, bamboo plays a role in soil stabilization and carbon sequestration, and offers raw material for biofuel production using species such as *Dendrocalamus asper* (Baral *et al*., 2021; Brady *et al*., 2023). Bamboo forms part of several mixed agroforestry systems as well as homegardens across the region, and has a high potential for bioenergy production as part of smallholder plantations, including in Indonesia, as well as for use as construction material, fencing and other wood products (Baral, Leksono and Seol, 2022).

Annex 4. Methodology

A4.1 Research questions, strategy and design

The objectives of the study identified in Chapter 1 were addressed by the research questions presented in Table 4. The study adopted a qualitative research strategy, which combined elements of cross-sectional ("survey") design with case studies. Table 4 also presents the study methods used to answer the research questions and the information sources that were drawn upon.

Table 4 Research matrix

Research objectives	Research questions	Research methods	Information sources
Identify situations where **agroforestry and other smallholder wood production systems contribute to wood supply**, while delivering multiple other products and services contributing to agrifood systems resilience across Asia-Pacific, illustrated by case studies.	1. What are the key characteristics of agroforestry and other smallholder wood production systems and the types of wood they supply across Asia and the Pacific? 2. What are examples of "insightful" (defined as a combination of positive productive, economic, social and environmental outcomes) agroforestry and other smallholder wood production models primarily supplying wood, while contributing other products and services? 3. To what extent do the above examples reaffirm known enabling factors for agroforestry and other smallholder wood production systems?	• Content analysis • Qualitative interviews • Case studies • Focus group (workshop)	• Key informants • Scientific publications • Technical publications • Grey literature
Identify **effective policy measures, incentives and investments to support upscaling agroforestry and other smallholder wood production systems** to contribute to wood production objectives while enhancing agrifood systems resilience, productivity and sustainability across Asia and the Pacific.	4. What are the key upgrading strategies for enhancing wood supply (wood production and wood-based value chains) from agroforestry and other smallholder wood production systems, and associated examples? 5. What further research and investments are needed to enable scaling up and out, and to deepen the contributions of agroforestry and other wood production systems to wood supply, while contributing to agrifood systems resilience through the provision of a broader range of products and services?	• Content analysis • Qualitative interviews • Focus group (workshop) • Case studies	• FAO agroforestry capacity needs assessment[5] • Scientific literature • Grey literature • Case studies • Key informants

The third research question: i) validated known enabling conditions for the success of agroforestry[6] and agroforestry-based value chains, ii) further expanded the list of these conditions as needed, and iii) investigated the validity of these enabling conditions in light of the case studies that form part of the overall study.

[5] See Springgay and Pajel (2024).
[6] "Agroforestry" refers to agroforestry and other smallholder wood production systems.

Enabling conditions for agroforestry, as identified in the literature, included:

- an enabling policy, legal and regulatory framework;
- tenure security;
- an institutional framework, sectoral coordination and access to extension services;
- the availability of effective incentives, financial mechanisms and quick return on investments;
- access to markets and value chains.

A4.2 Research and analysis methods

A4.2.1 Content analysis

The study team reviewed sources of information relevant to answering the research questions presented in Table 4. The focus was restricted to agroforestry systems with a specific emphasis on wood supply and associated value chains. Literature recommended by key experts was enriched through searches of scientific databases, including Scopus and Web of Science, as well as standard internet search engines. Documents analysed included articles and data in peer reviewed scientific and technical publications, grey literature and official statistics, focused geographically on the Asia and the Pacific region and published in the English language.

The preliminary literature review aimed to generate an understanding of the context and factors at play relevant for effective wood production from smallholder systems. This "narrative review" identified known factors of relevance to the production of wood from agroforestry and then adopted a deductive approach to test the validity of pre-identified factors in wider contexts.

A narrower subset of documents was subjected to qualitative content analysis, to identify underlying themes across publications relevant to answering the research questions. Data were collected in a spreadsheet, with columns corresponding to themes derived from the research questions (see sample in Table 5). Categories of data collection were refined once researchers were familiar with a basic corpus of relevant literature on agroforestry for wood supply from the region. Artificial Intelligence-based tools were used to assist the document review process.

Table 5 Data collection themes for qualitative content analysis of documents

Document	Characteristics of agroforestry systems supplying wood (main tree species, use/products, associated crops/products) + associated value chains	Examples of viable agroforestry models supplying wood and wood-based value chains	Challenges, barriers and success factors of agroforestry	Strategies that support upgrading of wood supply and wood-based value chains	Gaps and future tasks to support agroforestry for wood supply + associated value chains
Document 1					
Document 2					
Document 3					
.....					
.....					

A4.2.2 Qualitative interviews

A substantial part of the data for the study was collected through semi-structured qualitative interviews with key informants. Colleagues with a strategic overview of agroforestry, but without active involvement in programmes, projects or field implementation, were only asked strategic questions, whereas in-depth interviews were conducted with those with intricate knowledge and experience of wood production from smallholder tree-farming systems.

A4.2.3 Case studies

Case studies of individual situations of wood supply from agroforestry systems across the region were used to triangulate findings from content analysis and key informant interviews, and to illustrate key success factors. Case studies were applied using a cross-sectional study design framework *sensu* Bryman (2008: 55) to examine the cross-cutting attributes required for responding to the research questions. While cases were used as sampling units of a cross-sectional study design, they were also investigated intensively in their own right and used to illustrate the individual key study findings they represented well.

Projects were identified as potential case studies with the assistance of the FAO Field Programme Management Information System (FPMIS), as well as the databases of other relevant stakeholder organizations. Colleagues in charge of the selected projects were invited as key informants to the study and requested to prepare case studies on their projects following a common template. In cases where this was not possible, the FAO study team prepared the case studies based on data, information and close guidance provided by the project owners. Completed case studies were then subject to content analysis.

A4.2.4 Focus group workshops

Four expert panels were organized to present the study to a wider audience, refine and validate its methodology, and agree on a short-list of case studies. The panels also presented the draft report of the study to obtain stakeholder feedback, validate key findings and refine policy recommendations. Through these focus groups, the study was able to gauge consensus opinion and bring to light disagreements between stakeholders on key aspects of interest.

A4.3 Principles and criteria for sampling informants and case studies

A4.3.1 Stakeholder engagement

The initial range of stakeholders was identified by the study proponents and expanded using purposive sampling based on inputs from a subset of key experts within FAO. The sampling focused on: 1) representation of all key stakeholders, 2) geographic balance across the Asia and the Pacific region, including its four subregions identified by FAO,[7] 3) representation of key smallholder wood production systems, and 4) balanced representation of typologies of stakeholders.[8] The involved stakeholders reviewed and validated the study methodology, participated in key informant interviews, prepared the case studies and took part in an expert workshop.

A4.3.2 Selection of case studies

The following criteria were used for the selection of case studies:

- Cases should be “insightful” (see definition below).

[7] South Asia, Southeast Asia, East Asia and Pacific.
[8] Intergovernmental organizations, international NGOs, research and academia, the private sector and NGOs.

- Wood production should be one of the main aims of the system.
- The selection should be reflect a diversity of systems/species/functions.
- The selection should reflect geographical diversity.
- The selection should reflect a diversity of "upgrading strategies".
- The selection should reflect a diversity of stakeholders.
- Project closure dates should be recent (as relevant and to the extent possible).

For the purpose of the study, "insightful" cases of agroforestry are defined based on the classification of desired outcomes as listed in Table 6. These were classified along four broad axes of benefits provided by these systems (wood production, socioeconomic benefits, environmental benefits and social inclusion), with each case further qualified based on specific outcomes within each of these categories (e.g. provision of sufficient wood supply for household needs, improved nutritional outcomes, increased biodiversity, formation of cooperatives, etc.).

Table 6 Classification of outcomes of "insightful" cases

Products and services provided	Metrics	Potential classification
Wood production	• Quantity • Duration of continued production	• Subsistence/household needs • Local market • National market • Export market
Economic viability and other socioeconomic benefits	• Profits generated • Employment generated • Nutritional outcomes • Value chains developed/supplied • Demonstrated upscaling	• Reduced labour • Increased incomes • Profitability • Improved food security and nutrition
Environmental benefits	• Measures of agro-biodiversity • Biodiversity mainstreaming • Value of non-market ecosystem services • Resilience level • Deforestation rate • Erosion rate	• Ecosystem services • Improved biodiversity • Resilience/adaptation • Climate change mitigation • Reduced pressure on forests • Restoration
Social viability, inclusiveness and stakeholder engagement	• Level of conflicts • Land tenure security • Enabling policy and institutional environment	• Gender inclusion and transformation • Youth empowerment • Collective organization and solidarity • Policy support

A4.3.3 Ethical considerations

The study team strived to safeguard the rights and welfare of interview partners. The social science data collection process was administered in a transparent manner and interview partners were informed about the purpose of the study; the use, processing and storage of the data; and the disclosure of their contributions to the study. Participation in the study was free and voluntary.

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